EPA responses to MOVES3.R1 peer-review comments

Introduction

This document contains EPA's responses to the comments received from the External Peer Review of MOVES3.R1 Reports. The peer review was conducted by Eastern Research Group under Work assignment 4-16 under contract 68HE0C18C0001. The peer review was split into two parts*: Updates to the modeling of electric vehicles within MOVES*, and *Updates to refueling and NH3 criteria emissions*. In both cases, reviewers were asked to assess the changes made for MOVES3.R1, and to comment on the quality of the data, analysis, and assumptions that these changes are based on. The specific charge questions and the reviewers' detailed responses are provided in the Peer Review Report. The sections below include the text of the peer reviewers' responses sorted by subject, and the reports addressed followed by EPA's responses.

Updates to the Modeling of Electric Vehicles within MOVES

Report #1: Emission Adjustments

This report describes the adjustments that MOVES applies to emissions to account for the impacts of ambient temperature, humidity, air conditioning and vehicle inspection and maintenance programs. For MOVES3.R1, this report was updated to account for adjustments needed to model energy consumption from battery and fuel-cell electric vehicles. This includes new temperature adjustments as described in Section 2.7, and adjustments to account for electric vehicle charging and battery efficiency as described in Section 6. Also, in Section 7, we describe adjustments to energy consumption and hydrocarbon and NO_X emissions from internal combustion engine vehicles that account for the averaging, banking and trading provisions of light-duty regulations in the context of a growing population of electric vehicles.

The reviewers' comments were mostly positive; they generally found the resulting model inputs appropriate and consistent with both the physical and chemical processes involved in mobile source emissions, formation, and control, and with the existing data and research literature. However, they did note a number of areas for improvement as detailed below. For brevity, positive comments are not repeated here.

Reviewer 1 Shawn W. Midlam-Mohler, Ph.D.

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

> **Reviewer Comment for Section 2.7 and Appendix D (Temperature Adjustments for Electric and Fuel-Cell Vehicles):** There is likely more data out there, but the data selected is adequate. This is an area that will likely improve as OEMs develop better approaches for thermal management.
>
> > **EPA Response**: We do plan to update these values as thermal management technologies improve.

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): I am concerned that charging information for buses seems to be used for all electric vehicles. There were many data sources referenced, some of which seemed to refer to light-duty vehicles.

EPA Response: Yes, we used the Altoona bus data to determine the MOVES inputs for all electric vehicles, becausethe light-duty sources did not have the depth and specificity found in the Altoona data. Instead, we used the other sources as an independent check. We will explain the rationale more clearly in the text.

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?

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): It is not clear how the base bus data is adequately justified for use on other classes of vehicles. The approach of adjusting by age seems correct, however, it does not seem well supported by data.

EPA Response: There is no technical reason why charging efficiency would vary by vehicle class although we hope to revisit this question as charging technology matures and more data is available. Similarly, we plan to revisit the question of deterioration in battery efficiency as that data becomes available.

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer Comment for Section 2.7 (Temperature Adjustments for Electric and Fuel-Cell Vehicles): This could really benefit from showing the data and fits for the temperature correction as well as metrics of fit quality.

EPA Response: We agree that plotting the AAA data with the resulting MOVES curve would be helpful in illustrating this relationship. We intend to add this analysis to a future version of the report.

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): See previous comments. Some additional figures supporting the method would be valuable.

EPA Response: We have added a figure and supporting text. See previous responses.

Reviewer Comment for Section 7 (Averaging, Banking and Trading with Electric Vehicles): Some additional figures/tables would be helpful to describe the method. For instance, elaboration of Eq. 7-2 with some standard assumptions and across the model years in Table 7-1 would be helpful.

EPA Response: We have added an example calculation and a table showing example adjustments for various model year.

Reviewer Comment for Appendix D (Consistency of MOVES EV Temperature Adjustment with Other Sources): This does mitigate some concerns I had with Section 2.7, however, it does seem that more rigor could be applied here.

EPA Response: We do not feel the data sources presented in Appendix D are appropriate for a more rigorous analysis than the general comparison we presented. We will add a more detailed explanation for each study in Appendix D of the MOVES4 technical report.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics?

Reviewer Comment for Section 2.7 and Appendix D (Temperature Adjustments for Electric and Fuel-Cell Vehicles): Perhaps. Without a figure showing the fit quality of Eq 2-17 and error metrics it is not possible to say.

EPA Response: As we explain in our response above, we intend to add this analysis to a future version of the report.

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): The method of having an age-based adjustment is valid. See above caveats on the source data.

EPA Response: See response to charging data concerns above.

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?

Reviewer Comment for Section 2.7 and Appendix D (Temperature Adjustments for Electric and Fuel-Cell Vehicles): Perhaps. As noted above, I feel that there is more that should be done to ensure the best approach is being used here.

EPA Response: As we explain in our response above, we intend to add this analysis to a future version of the report.

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): Concerns noted above.

EPA Response: As we explain in our response above, there is no technical reason to expect charging efficiency would vary by vehicle class although we hope to revisit this question as charging technology matures and more data is available. Similarly, we hope to revisit the question of deterioration in battery efficiency as that data becomes available.

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?

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): Concerns noted above.

EPA Response: As we explain in our response above, there is no technical reason why charging efficiency would vary by vehicle class. The electric vehicle supply equipment (EVSE) used for LD and HD applications is generally the same. As the technology matures and more data becomes available, we can revisit this question.

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar??

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): Concerns noted above.

EPA Response: As we explain in our response above there is no technical reason to expect charging efficiency would vary by vehicle class although we hope to revisit this question as charging technology matures and more data is available.

Reviewer 2 Guoyuan Wu, Ph.D.

Does the report 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?

Reviewer Comment for Appendix D (Consistency of MOVES EV Temperature Adjustment with Other Sources): Mostly

EPA Response: Consistent with our response to comments above, we will add more discussion of the sources in Appendix D, including vehicle information, study design, and results.

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?

Reviewer Comment for Section 2.7 and Appendix D (Temperature Adjustments for Electric and Fuel-Cell Vehicles): Mostly

EPA Response: We have added more detail to clarify why we selected the AAA data for our primary analysis and how we used supplemental data to evaluate the resulting temperature adjustments.

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): Mostly

EPA Response: We have added more detail to clarify why we selected the Altoona bus data for our primary analysis and how we used supplemental data to evaluate the resulting charging efficiencies.

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer Comment for Section 2.7 (Temperature Adjustments for Electric and Fuel-Cell Vehicles): on Page 43, it is said "Relative to room temperature, the AAA found a 39% reduction in miles per gallon equivalent (MPGe) at 20 F and a 17% reduction in MPGe at 95°F, corresponding to a 64% and 20% increase in energy consumption, respectively.", but it is not very straightforward to relate these figures; b) it is not clear to me why 67°F is calculated as the minimum heat index.

EPA Response: We have added text to (a) clarify the use of the AAA data and (b) better explain the minimum temperature in the MOVES air conditioning demand function.

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): a) It is not clear why modeling of emissions from power plant and associated air quality changes needs to be considered for BEVs? By contrast, does it mean that the fuel production, evaporation, or other loss during transportation need to be considered also for ICEVs? b) Will Table 6-1 be applied to FCEVs, too?

EPA Response: (a) We have added text to explain that MOVES energy demand can be used as an input to estimate "upstream" emissions for all types of vehicles. (b) We have added a footnote to explain that the MOVES code structure requires us to apply the charging efficiency in Table 6-1 to FCEV energy consumption and how we mitigate that.

Reviewer Comment for Appendix D (Consistency of MOVES EV Temperature Adjustment with Other Sources): on Page 86, in Figure D-1, it is not clear how the curve was fitted, e.g., least square?

EPA Response: As noted in the text, the curve in Figure D-1 is not derived from the data shown in the figure but, instead, is included for comparison. We have updated the figure for clarity. In addition, we have updated the discussion in Section 2.7 to better explain how the coefficients for the MOVES curve were derived from the AAA data.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics?

Reviewer Comment for Section 6 (Electric Vehicle Charging and Battery Efficiency): Mostly

EPA Response: We have added detail to Section 6 to better explain our calculations and the rationale behind our approach.

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer Comment for Section 7 (Averaging, Banking and Trading with Electric Vehicles): On Page 69, it is said "Individual counties will, of course, have different electric vehicle sales fractions, but emission compliance is determined at the national level, thus we use MOVES national default values in these calculations even when MOVES is run at county or project scale". However, this may vary quite significantly, e.g., California vs. Iowa.

EPA Response: We have revised this section of the report to more clearly explain that because the fleet-wide averaging compliance determination is based on national sales rather than the local fraction of EVs, the national EV fraction is the correct number to use in this calculation.

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?

Reviewer Comment for Section 7 (Averaging, Banking and Trading with Electric Vehicles): On Page 77, the sampleVehiclePopulation should be varied with state or even county. The number between two states could be very large.

EPA Response: As noted above, we have revised this section of the report to better explain when and why we use national EV fractions (stored in the SampleVehiclePopulation table) and when the use of state or local fractions is appropriate.

Report #2: Exhaust Emission rates for Heavy-Duty

The changes in this report do not directly document updates for electric vehicles but includes updates related to HD internal combustion engine (ICE) exhaust emissions which are tangentially related to the introduction of EV modeling in MOVES. Allowing for the modeling of EV combination long-haul trucks in MOVES also facilitated the modeling of CNG combination long-haul trucks, which requires updates to ICE emission rates. The updates in MOVES3.R1 are documented in Section 2.3 (Extended Idling Exhaust Emissions), Section 4 (Heavy-Duty Compressed Natural Gas Exhaust Emissions), and Section 6.3 (Heavy-Duty Gasoline and CNG Crankcase Emissions).

The updates made to these sections pertained specifically to the addition of emissions estimation data and methods for CNG combination long-haul trucks. However, we welcomed review and comment on our CNG emissions estimation methodology in general.

Reviewer 1 Shawn W. Midlam-Mohler, Ph.D.

Does the report 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? Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer comment: Sections 2.3 and 4 are very well documented and clear. Section 6.3 is much sparser and based on some assumptions that are not clearly stated.

EPA response: The reviewer did not provide any specific criticism, recommendations, or areas of improvement on this topic. We address their concern with Section 6.3 in our response below.

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?

Reviewer comment: The methods are described well enough to be clear. As noted above, the approach in 6.3 is not well documented.

EPA response: The reviewer did not provide any criticism, recommendations, or areas of improvement on this topic. We address their concern with Section 6.3 in our response below.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics? Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment: With the exception to 6.3, the methods used seem appropriate and reasonable.

EPA response: The reviewer did not provide any criticism, recommendations, or areas of improvement on this topic. We address their concern with Section 6.3 in the following response.

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.

Reviewer comment: Section 6.3 seemed to be lacking rigor. I am not aware of any sources that can provide context to the assumptions made regarding heavy-duty CNG and gasoline engine crankcase emissions, however, I could not conduct a literature review with the scope of this review. I feel that there is some peer-reviewed literature out there that could support this.

EPA response: Due to resource constraints, the CNG crankcase updates used the same MOVES3 ratio between the running emission process and extended idle process for CNG.. We did not revisit the existing crankcase ratios for the running process and thus we felt a less rigorous approach was appropriate here.

However, we have updated this section to more clearly discuss our limited review of the scientific literature. Unfortunately, HD exhaust emissions from gasoline and CNG vehicles tend to be studied far less than diesel, and crankcase is far less studied as an emissions process than tailpipe emissions (this is, in part, due to difficulties in measuring crankcase emissions in vehicle tests). Still, our review found studies suggesting that MOVES underestimates crankcase emissions from CNG vehicles, with particular concern for methane emissions. We will update the section to note this concern and we will consider updating the CNG crankcase to exhaust ratios in a future version of MOVES as additional data and studies are published.

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?

Reviewer comment: Yes

EPA response: The reviewer did not provide any criticism, recommendations, or areas of improvement on this topic.

Reviewer 2 Guoyuan Wu, Ph.D.

Does the report 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? Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer comment:

Section 2.3:

1) on Page 115, "Testing was conducted on 12 heavy-duty diesel trucks and 12 transit buses in Colorado by McCormick et al. Ten of the trucks were Class 8 heavy-duty semi-tractors, one was a Class 7 truck, and one of the vehicles was a school bus." Does it mean a school bus was counted as HD diesel truck?

2) on Page 117, "Emissions data from the references in the data sources section (2.3.1.1) was classified into one of three idle conditions. The first condition, which has a low engine speed (<1,000 rpm) and no air conditioning is representative of curb idle. The second condition is representative of extended idle with higher engine speed (>1,000 rpm) and no air conditioning. The third represents an extended idle condition with higher engine speed (>1,000 rpm) and air conditioning", then what about the four condition which has a low engine speed but with air conditioning;

3) on Page 117, "For both the MY 1960-1990 and 1991-2006 vehicles, using the data summarized in Appendix E, adjusted emission rates were calculated for each pollutant by weighting the overall "high speed idle, A/C on" results by 0.33 and the "low speed idle, A/C off" (i.e., curb idle) results by 0.67 to account for the fraction of idling at high and low engine speeds", where do those two numbers, 0.33 and 0.67, come from?

4) on Page 120, Table 2-47, are those two temperatures representative enough and consistent to be applied across different sourceTypes.

EPA response:

1) EPA did not use the data from the school bus as a HD diesel truck. We will clarify this in the text of the report.
2) Because air conditioning requires a higher energy output from the engine, there is generally no engine operation at low engine speed while air conditioning is on, which is why the condition was not included in the data analysis. We added a footnote to the report explaining this.
3) The weighting of high and low engine speed for extended idle is discussed on the previous page to the paragraph cited, with a list of reference studies used to estimate the weighting used and the proportion of low and high speed idle in each study.
4) In MOVES, extended idling emissions are only modeled for a single source type, combination long-haul trucks.

Reviewer comment: Section 4: on Page 189, it is said "The methane fraction from CNG vehicles is 89% and 96% for model year groups 1960-2004 and 2002-2060 respectively, as documented in the Speciation report", so how to handle the overlapped years, i.e., 2002 – 2004?

EPA response: This is a mistake in our documentation. MOVES breaks the rates into model year ranges of 1960-2001 and 2002-2060. We are updating our documentation (including both the heavy-duty exhaust report and the speciation report) accordingly.

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?

Reviewer comment: Section 2.3: on Page 123, it is said that "We initially expected the data to show a decrease in the extended idle emission rates beginning in MY 2008 to account for the California Clean Idle Certification (all MY 2008 and later trucks were clean-idle certified). However, no reduction was observed. We also expected to observe a decrease in 2012, with the full implementation of SCR, but this was also not the case.", so are there any hypotheses to explain these observations?

EPA response: Our hypothesis is that emission reduction technology was phased in by manufacturers on a timeline sooner than the respective regulations. However, we have no hard data to back up this hypothesis and therefore don't include this hypothesis in the report.

Reviewer comment: Section 4: on Page 200, it is said that "for $PM_{2.5}$, in MOVES3, ages 0-3 and 4-5 have no deterioration and the MOVES2014 light-duty $PM_{2.5}$ deterioration factor for age 6-7 is applied to all CNG $PM_{2.5}$ emission rates for ages 6+, thus making the $PM_{2.5}$ and gaseous pollutant methods more (but not fully) aligned. Note that, unlike gaseous pollutants, the $PM_{2.5}$ deterioration factor does not vary between operating modes for a given age group. See Section 3.1.2.1.3 for more details and Table 4-4 for a comparison between MOVES3 and MOVES2014". It is not clear to me if this statement is an assumption or an observation.

EPA response: This is documented in Section 3.1.2.1.3. It is based on an observation of light-duty data, which we then assumed extends to heavy-duty because we did not have specific heavy-duty data. We have updated the text to make clear that this is a description of our modeling rather than real-world data.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics? Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment:

Section 2.3:

a) Usually the technology market (e.g., SCR) penetration rate has strong correlation with the MY. This needs to be paid attention;

b) on Page 127, it is said "First, MHD trucks are estimated to account for only 5 percent of long-haul combination trucks in the US and therefore, they are a minor contributor to the emissions from extended idling trucks", but I don't think this is an appropriate rationale to

support the statement “The extended idle emission rates for MHD are assumed to be the same as HHD for the following two reasons”.

EPA response:

a) We agree with this statement. As explained in Section 2.3.2.2, we have used model year groups to reflect the correlation between technology adoption rates over time and emissions.
b) This statement is not meant to justify the assumption based on data on its own, but instead to note that differentiating the rates between MHD and HHD (especially considering the results of the Khan et al. study, cited right after this text, which showed very similar extended idle emissions) has a minimal impact on the total emissions estimated by the model. We will update the text to make this clearer.

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.

Reviewer comment:

Section 2.3:

a) The earliest dataset seems to be Year 1984, so why MY range starts from Year 1960?
b) why the emissions rates for different pollutants, e.g., from Figure 2-65 to Figure 2-69, were grouped by year differently?

EPA response:

a) MOVES must model the calendar year 1990 and models vehicles of age 30 years or younger. Therefore, it must model emissions from model years as far back as 1960. However, we only have data for model years 1984 and later. As the figures show, we assume the older model years have the same emission rates as MY 1984.
b) In MOVES, model year groupings differ by pollutant because model-year associated technology changes may affect some pollutants but not others, and because data availability may vary by pollutant and model year, as some studies have data only for select pollutants.

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?

Reviewer comment: Yes for all sections**.**

EPA response: The reviewer did not provide any criticism, recommendations, or areas of improvement on this topic.

Report #3: GHG & Energy Consumption Rates

This report describes the energy and greenhouse gas (GHG) rates in MOVES and documents the data sources and analyses we used to develop the energy and greenhouse gas emission rates. The sections sent for peer review include Section 2.a.iii (now 2.a 1.1.3) Light-Duty Running Energy Rates for Electric Vehicles; Section 2.b.i (now 2.b 1.1.5) Heavy-Duty Battery Electric and Fuel Cell Energy Rates; Section 2.b.ii (now 2.b 1.1.6) Hotelling Shore Power Energy Consumption; Appendix C EV ALPHA Parameters and Results; and Appendix D Derivation of Heavy-Duty EV and FCEV Energy Efficiency Ratios.

The reviewers generally agreed that the report describes 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 and the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics, with questions being addressed as below.

Reviewer 1 Shawn W. Midlam-Mohler, Ph.D.

Does the report 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?

Reviewer commented on Section 2.b.1 – not clear which of the reference cited are the source for the EER

> **EPA Response:** We do not have a citation for energy efficiency ratios (EER) in the context of modeling electric vehicles, because it is simply a short-hand for the energy used by electric vehicle relative to the energy used by equivalent diesel vehicles. The idea is used in the evaluation of HVAC systems, but here we are asserting the EER can capture EV energy consumption. In the report, we updated the text to be clearer that we do not have a specific study to cite. We rearranged some text and table to indicate the data sources for EERs.

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer commented on Section 2.a.iii – not clear ALPHA models were used to simulate vehicles with known economy information. Using the model output rather than the known experimental values includes unnecessary errors. This is particularly true for the light-duty vehicles in which there is a wide range of vehicle data publicly available.

> **EPA Response**: The known experimental values can be used to validate model output (in fact, we ensured the average MPGe values modeled by MOVES were consistent with certification testing values), but are not sufficient on their own to develop energy consumption rates by operating mode. This is because we need second-by-second operation and energy consumption data to develop operating mode-specific rates. Instead, we used the output from the ALPHA model that allows for estimating energy consumption at the operating mode level. The ALPHA model has been independently peer reviewed and is also used to support EPA rulemakings. We hope to update future versions of MOVES when more data is available.

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?

Reviewer commented generally yes, one additional concern in lacking robust data in hotelling section 2.b.ii

EPA response: We agree that lack of data for electric vehicle hoteling is a concern. As the reviewer also commented, it (the current EPA approach) seems to be the best approach possible applied given the sparsity of data. We hope to update future versions of MOVES when more data is available.

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?

Reviewer commented yes, but restated the question in section 2.a.iii about the use of ALPHA

EPA Response: As noted above, we used the output from the ALPHA model since we are not aware of any data on EV energy consumption by operating mode required for modeling. We hope to update future versions of MOVES when more data is available.

Reviewer 2 Guoyuan Wu, Ph.D.

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer comments:

Section 2.a.iii (a 1.1.3), it would be better to add data from third-party certification.

Section 2.b.i: Currently, MOVES focuses on 1-D speed trajectories (drive cycle), but the lateral movement may have impacts on energy consumption. There should be some additional data to address this issue. This suggestion applies to other sections and reports, too.

EPA Response:

For section 2.a.iii (a 1.1.3), we are always looking for potential data source to improve our model.

However, as noted in the response to Midlam-Mohler above, due to the lack of 1 Hz data, our current light-duty electric vehicle energy rates are based on ALPHA modeling. While data would be preferable, we feel that ALPHA provides reasonable alternative. As stated in ALPHA website "EPA engaged ICF International to perform a peer review of the ALPHA Full Vehicle Simulation Model. This peer review process was carried out under EPA's peer review guidelines. The entire model and all subsystems were unlocked for complete transparency. A number of independent subject matter experts provided reviews and comments on the methodologies used in the model."

Our lab has ongoing effort to build the capability to test BEV energy rates, and we hope to utilize those data when they are available for the majority BEV market share holders.

For section 2.b.i (b 1.1.5), we believe lateral movement impact on energy consumption is not significant compared to some other adjustment factors that we have prioritized and accounted for in MOVES, for example, temperature impacts and charging efficiency.

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer comments: Section 2.a.iii: on Page 15, it is not clear why some parameters are chosen for the custom-built cycle, e.g., why "50 hard accelerations", why "from 0 to about 75 – 80 mph", why "data during deceleration back to 0 mph was ignore".

Appendix D: on Page 49, I don't know how the number "1.61" was calculated. If averaging the last column, the value should be 1.68. If taking the median of the last column, the value should be 1.60.

EPA Response:

For section 2.a.iii, we added text to add more detail and justification for the custom cycle.

For Appendix D, we believe the current description is sufficient for the calculation. As explained in the text above Table D-5, the 1.61 value is not an average across vehicle categories. Instead, it is based on the GREET value for Combination Long Haul Vans because we expect most FCEVs will be used in long-haul applications. As noted, we use the GREET ratio with a 15% reduction to account for battery and charging losses. (1.9*0.85=1.61)

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment:

Section 2.a.iii: we may consider to add estimation error bars in addition to estimation itself to partially address the uncertainties in the data. This suggestion may apply to most of the sections that were reviewed in this task.

Section 2.b.i: 1) it would be better to differentiate in-vehicle technologies used between BEVs and diesel vehicles; 2) EER should be function of other parameters than "speed" only, such as opMode, acceleration, model year. 3) it would be better to have the regulatory class or source type is defined to match with the vehicle classification defined by FHWA. This would provide a consistent foundation for analysis, modeling and simulation of traffic-related emissions or energy consumption.

Section 2.b.ii: on Page 23, "we assume that the energy consumption for all fuel types using shore power is the same." This seems to be a strong assumption as different technologies (available for different fuel type) in different MY may have different energy consumption.

Appendix D; on Page 48, it is said that "Table D-4 shows EERs averaged for each available source type with equal weighting given to each reference", but I would recommend to use median rather than average for the representative EER number. This may be a more robust way

considering the large variations in data and potential outliers. This suggestion may apply to other sections or other reports in this review task.

EPA Response:

For section 2.a.iii (a 1.1.3), we will consider adding estimation error bars as suggested by the reviewer when we update Figure 2-5 and Figure 2-6 for future versions of MOVES.

For section 2.b.i and section 2.b.ii, at this time, we are not aware of existing data that would allow us to differentiate vehicles as suggested here. We do expect to refine our analysis in the future.

For Appendix D, we chose the averaged EERs instead of medians because we believe the numbers we have are within reasonable range that reflect vehicles operating in different conditions. The variation in values is consistent with our expectations given expected activity patterns and appears to be valid and representative, with no values we would consider outliers.

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?

Reviewer comment: the reviewer agreed with this statement for section 2.a.iii, but commented "not completely (agree)" for section 2.b.i. when further asked if not, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs, the reviewer commented that in section 2.b.i, the assumption "Due to a lack of available data, we define EER only by source type and apply the same ratio for all heavy-duty regulatory classes and model years." seems to be too strong.

EPA Response: To make the statement less strong per reviewer's suggestion, we have revised our language to "Due to a lack of available data from our research and literature study, we define EER only by source type and apply the same ratio for all heavy-duty regulatory classes and model years."

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

Reviewer comment:

Section 2.a.iii: on Page 16, it is not clear why in opMode Bin 16, the energy rate of EV is higher than ICEV. The trend is not

Appendix C: in Table C-2, it seems that the overall range is underestimated; UDDS drive cycle (City) is overestimated, but results of HWY drive cycle are underestimated. More explanation is needed. Is it because overestimate regenerative braking effect and overestimate energy consumption for high-speed scenarios? Or drive cycles of EVs are different from drive cycles of conventional vehicle as pointed out by some research.

EPA Response:

For section 2.a.ii – Vehicle weight contributes to their energy demand, and EV weight tends to be higher than ICE vehicles. Operating mode 16 covers low-speed, high-acceleration operation, so our hypothesis is that the higher energy consumption is due to a greater vehicle mass for EVs.

For Appendix C, we don't have any direct evidence to state that the range difference is caused by an overestimation of regenerative braking effects. We agree with the reviewer that EVs may very likely have different regular driving cycles compared to ICE vehicles, which are what UDDS and HWY were originally designed for.

Report #4: Population and Activity of Onroad Vehicles

This report describes the sources and derivation for onroad vehicle population and activity information as stored in the MOVES default database. Section 5.2 Sample Vehicle Population was sent for peer review. To match source types to emission rates, MOVES must associate each source type with specific fuel types, technologies (EngTech), and regulatory classes. This section discusses how we model shifts in historical and projected vehicle distributions with model year, including the updates to electric vehicle market penetration in MOVES3.R1.

The reviewers generally agreed that the report describes 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, and the description of analytic methods and procedures is 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.

Reviewer 1 Shawn W. Midlam-Mohler, Ph.D.

Does the report 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?

Reviewer comment: Yes. The formatting of the references could be improved to a more formal structure. For instance, the data is referenced as "2020 IHS data" without a formal reference. Other data is properly cited but it should be consistently cited.

EPA Response: There is a formal citation for the 2020 IHS data in the previous section of the report, but given the length and complexity of this document, we have added an end note to the formal citation in this section, too. We also updated the citation for IHS to reflect the company's recent name change. For example, "Vehicle in Operation Registration Data, IHS Markit-Polk, S&P Global, July, 2020" for IHS2020

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?

Reviewer comment: Motorcycles were not considered due to sparsity of data and the sparsity of alternative fueled motorcycles. It is likely negligible; however, this should be cited with some sources. The remaining assumptions seems appropriate and reasonable and were backed up by citations.

EPA Response: As shown in Tables 3-1 and 4-4, motorcycle activity is a very small fraction of the overall vehicle activity. We were not able to find sources for alternative fueled motorcycles, and that's why we did not update them and thus have no citations for them. We have clarified this in the report.

Reviewer 2 Guoyuan Wu, Ph.D.

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.

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment:

On Page 40, it is said that "However, electric refuse truck distributions for model years 2019 and earlier were calculated using 2019 Annual Production Volume Reports into Engine and Vehicle Compliance Information System reported to EPA, and motor homes used the 2014 IHS data for all model years 2013 and earlier." We should use projection to get 2020 results for consistency on electric refuse truck distributions.

On Page 44, it is not clear where "1500 vehicle sale" comes from. Also, for Equation 5-3, I would suggest to differentiate FT and ET (if applicable). It does not make too much sense to only look into MY. Also, the sum of Eq. 5 -3 I does not equal to 1?

EPA Response:

For the refuse truck comment, we have added text to the report to clarify that we used the AEO-based projection methodology for all 2020-and-later single unit trucks, including motor homes and refuse trucks.

For the glider comment:

First, regarding the estimate of 1500 glider sales, we have added text to clarify our calculation:

To estimate 2019 sales, we had limited data from the glider assembler manufacturers (only 27 assembler manufacturers reported 2019 sales at the time of the analysis, all of which sold less than 50 gliders per manufacturer). The two major glider kit manufacturers informed EPA that they had stopped production of glider kits in 2018. As such, we assumed that the 2019 glider vehicles would be 1500 vehicle sales, which is calculated from 50 gliders per manufacturer and 27 reported assembler manufacturers, rounded to the nearest 500.

For equation 5-3, fuel type and engine type are not applicable here since all gliders are conventional diesel. We added a sentence in the report right before the equation to clarify. The equation should not sum to 1 because the equation is intended to calculate the fraction of glider trucks compared to all combination trucks.

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.

Reviewer comment: It is noted that "As the 2020 IHS data does not contain complete information on model year 2020 and later vehicles, we held regulatory class distributions for these vehicles constant at the model year 2019 values". There could be a better way (e.g., regression) to project the RC distributions for future years (after 2020) by examining these distributions from 2014 and 2020 HIS data. The "constant" assumption, though simple, may result in a significant bias. Another example, in Section 5.2.2, it is said that "The market shares for other fuel types were proportionally reduced so that the total market share for all fuel types sums to 100%." This might not be a reasonable assumption. Due to the nationwide policy for sustainable transportation, the market shared for clean energy powered passenger cars (besides electric cars) should be increased, which may be justified by other sources (e.g., registration database from DMV).

EPA Response: It seems that the approach we are using to forecast into the future was not clearly explained in the report. Therefore, we have now updated the text to clarify. For example, we removed the sentence describing how regulatory class distributions were held constant at model year 2019 values because it did not accurately portray the current analysis for heavy-duty vehicles. For model years 2020 and beyond, we rely on the sales projections in the Annual Energy Outlook, which include differential changes by weight class grouping. To clarify this, at the beginning of section 5.2.2, we added "In general, the 2014 IHS data were used to calculate fuel type, regulatory class, and EngTech distributions for model years 2000-2013, and the 2020 IHS data were used for model years 2014-2019. For model years 2020 and later, we generally relied on projections in Annual Energy Outlook. For earlier model years not described here, we generally retained the analysis from previous models, as described in Appendix A." We also added more details in each sub-section in Section 5.2.2 to describe the regulatory class and fuel distribution data source for each source type.

MOVES models only the passenger car fuel types described in Section 5.2.2. To improve clarity, we replaced "The market shares for other fuel types were proportionally reduced so that the total market share for all fuel types sums to 100%." with "The fuel distributions for gasoline, diesel, and E-85 capable passenger cars for these model years were derived from Department of Energy car sales projections from AEO2021's table Light-Duty Vehicle Sales by Technology Type."

Updates to Refueling and NH3 Criteria Emissions

Report #1: Exhaust Emission rates for Light-Duty

This document describes the data and methods used to develop exhaust emission rates for gaseous pollutants (CO, NOx, THC, NH_3) and particulate matter (PM_{25}) for light-duty vehicles in MOVES. For MOVES 3.R1, this report was updated to describe the methodology used to generate new ammonia

(NH_3) exhaust emission rates (Section 6) based on near-road remote sensing data and updates to the nitrogen oxides (NOx) composition for light-duty diesel vehicles (Section 8.3).

The comments received were mostly positive regarding methods and data sources used but requested more clarity in the description of methodologies and provided other references and/or data sources to complement what we had developed.

Reviewer 1 Thomas D. Durbin, Ph.D.

Does the report 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?

Reviewer comment:

Section 6.1.1 – it looks like the Sierra report used data from the Harvey reference 94 for the 1975-1980 vehicles, so that reference could be used for the 3rd sentence in the section. The other main study used by Sierra work for NH_3 (Durbin et al., 2002), did not have any pre-1981 vehicles.

For table 6-2, it lists the different RSD testing campaigns. Are there any references that describe these testing efforts? Its realized that the data comes from the website, but its probably not realistic that most readers would be able to access and look at these data in too much detail. It would be useful to have some additional background on the different testing campaigns that might be available through literature references (even if these articles may not include NH_3 emissions).

Section 6.1.2.4. 2nd paragraph. It talks about the results of the MOVES2010 correlation on NH_3 with power based on CE-CERT studies. The final sentence talks about this being reported in other studies, but these are actually just the CE-CERT studies, so they are not really "other" studies.

> **EPA Response:** Thank you for your suggestions. We added the reference mentioned at the end of the third sentence of Section 6.1.1. Regarding Table 6-2, we have added columns containing mean VSP and mean MY for each campaign extracted from the CRC reports available on the website. Finally, we have removed the sentence referring to "other" studies and clarified the source of the references in the last sentence of the 2nd paragraph in section 6.1.2.4.

Reviewer comment:

For the NO, NO_2, HONO ratios in section 8, for the light-duty diesel vehicles, these assumptions are discussed in the corresponding report #2 on heavy-duty diesel vehicles, and comments related to this can be found in the report #2 charge questions. It should be noted that the second to last reference should be 105 instead of 111, as 111 references the older 2020 report on this topic.

For the NO, NO_2, HONO ratios in section 8, for the light-duty gasoline vehicles and motorcycles, it appears that the data trace back to the Sierra Research data analysis and use in 2012, which in turn is based on an earlier CE-CERT (with 2001 and older vehicles).

> **EPA Response:** Thank you. We've addressed your comments in our Report #2 responses, below, and have updated the references as suggested.

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer comment:

CARB/UCR has recently conducted a study of the impacts of E15 on modern vehicles that included NH_3 emissions. In general, the emission rates are below 10 mg/mi, which could be used to check against some of the later 2020 and 2021 RSD studies when they get incorporated into the model. https://ww2.arb.ca.gov/resources/documents/comparison-exhaust-emissions-between-e10-carfg-and-splash-blended-e15

Another recent study is the following: Abualqumboz, Motasem S., Randal S. Martin, and Joe Thomas. "On-road tailpipe characterization of exhaust ammonia emissions from in-use light-duty gasoline motor vehicles." Atmospheric Pollution Research 13, no. 6 (2022): 101449.

UCR/CE-CERT has characterized NH_3 emissions from light-duty diesel vehicles in the CRC AVFL-17b study. https://crcao.org/wp-content/uploads/2019/05/CRC-Final-Report_AVFL-17b.pdf

I don't know of other key sources of NO/NO_2 data for light-duty gasoline vehicles, but perhaps some data might be available to EPA through either the EPACT or internal EPA studies.

EPA Response: Thank you for recommending these NH_3 studies. We will review them and incorporate their data in future updates as appropriate. In terms of NO/NO_2, most EPA vehicle emission testing does not measure NO and NO_2 separately, but we will consider a more detailed review of historical EPA test data for future analysis.

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?

Reviewer comment: Table 6-1. The emission rates are given in g/hour. It would at least be useful to provide some information related to how many miles are covered in the hour, or what other assumptions are made for this estimate.

EPA Response: We agree that the MOVES2010 work deriving NH_3 emission rates for MY 1960-1980 from the research study results is not sufficiently documented; Despite our efforts to review the research study, the contractor report, and previous MOVES documentation, we couldn't find the detail the reviewer suggested we add. However, since this table describes only pre-1980 model year vehicles and thus the emissions contribute only to MOVES runs for calendar years 2010 and earlier, we do not intend to investigate further.

Reviewer comment: Section 6.1.2.3 – 4th paragraph. It talks about the MOVES2010 using scaling factors for the 1981-1996 model year group, but its not clear how these were applied. Were the scaling factors to make the emission rates younger than 10 years old smaller.

Section 6.1.2.3 – 4th paragraph. The discussion on the age-related scaling factors is not totally clear to me. There is one set of factors that scale up from the 0-3 age group, and then there is a second that scales down from the 15-19 year age group. I guess the first question for me is what

is the average age of the fleet in these different age groups, since presumably you are taking the average emission factor and adjusting it up or down for older/newer vehicles, respectively. The remaining sections talk in greater detail about the specifics of how this method is applied for different model year groups, but its still hard to follow since the idea is probably not as clear as it could be from the start.

> **EPA Response:** We recognize the need for more clarity, so we have added and/or modified text in different paragraphs along the discussion of scaling factors. The aging approach for each model year group is slightly different given the data available in each model year-age combination. The specific points mentioned are addressed below:
>
> In MOVES2010, the scaling factors were used to scale up emissions from the young groups to the oldest group. In the current analysis, since we only had data for older vehicles in the 1981-1995 group, we assume that the same aging trend presented in the Sierra Report is applicable here, independent of the mean age within this MY group, and use the same factor from MOVES2010 to scale down emissions from the older age group to the young age group.
>
> For the MY group 1996-2003 where 2 sets of aging ratios are presented, we have added text to clarify that for this specific MY group the set of aging ratios based on the age group 15-19 is used to generate rates because there is data for this age group in all the model years within the 1996-2003 range.

Reviewer comment:

In looking at Figure 6-2, 6-4, and 6-5 compared to figure 6-6 I am wondering if there is a better way of typing things together. I think it would be useful to understand where the speed acceleration profiles from the RSD data fall relative to the bins in Figure 6-6. Are the RSD data more for low/medium or high power events?

> **EPA Response:** Given the limitations in operating conditions of RSD datasets explained in the text, the likely delay between the time of emission formation and measurement, and the fact that our methodology scales measured fuel-based rates with MOVES fuel consumption rates as shown in Equation 6-7, we consider it out of scope to include detailed information on the operating mode distribution of each campaign included here. However, from the information available in the FEAT archived reports, we included the mean VSP reported for each campaign in Table 6-2. In general, the campaigns focus on locations that allow for a low/medium acceleration mode but in some years, there were exceptional situations (e.g., traffic lights not working) that changed this pattern, as documented in the articles and reports stored in the FEAT archive. We have added this information to the text.

Reviewer comment: Figure 6-7 is useful, showing how the emission rates vary over time (i.e., calendar years). It is a bit interesting to see how there are little bumps in the distributions that must be a product of the assumptions/data limitations. The other thing is that looking at the 2004-2010 data, the emission rates are actually lower for the 2024 vs. 2017 calendar year, which is a little confusing, since the corresponding paragraph talks about the aging impact being seen.

Is there some off-setting factor that the older vehicles are driving less aggressively that could contribute to that trend.

EPA Response: The factor offsetting the aging effect for MY2004-2010 is the reduction in activity (miles driven) for those model years in calendar year 2024 compared to calendar year 2017 and this is reflected in the g/mile values shown in Figure 6-7.

Reviewer comment: For section 8, perhaps for the light-duty gasoline vehicles, that a reference could be added to the CE-CERT study that was actually used to develop the NO/NO_2 ratios. This would allow the reader some direct information on what data was primarily used for the estimates, as opposed to going back to the 2012 report, which in turn uses the older CE-CERT study.

EPA Response: Thank you for the suggestion. We have maintained the reference to the Sierra Report because it contains analysis specific to MOVES and mentions other studies in addition to the CE-CERT work

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer comment: Figure 6-1 to 6-7 are useful. Table 6-4 and associated other tables would probably be more useful if the underlying discussion was clearer.

The tables in section 8 seem suitable to present the NOx composition data.

EPA Response: As mentioned above, we have added text to clarify the discussion on age-related scaling factors and we hope the methodology is clearer now.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics?

Reviewer comment: Overall, I think the methods are reasonable, although some could be clarified further to make the report easier to understand. It would be useful to understand how the RSD data compares in terms of what ages and what operating modes represent the typical averages in Figure 6-2.

EPA Response: Thank you for this suggestion. We have modified Figure 6-1 to include a tile plot of vehicle age by calendar year of RSD measurements to provide information on the general age distribution of the sample; we have also added the mean Model Year for each campaign in Table 6-1. For the operating mode suggestion, see our prior response.

Reviewer Comment: For section 8 on NOx composition, the methods seem appropriate, with the main limitation being with the input data, although this is less of a limitation for the heavy-duty data which would make a more significant contribution for NOx.

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment: Again, the main suggestion is just to clarify the discussion related to how the methods are applied.

EPA Response: Addressed above.

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?

Reviewer comment: Section 6.1. It talks about NH_3 emissions during cold start, and that elevated NH_3 emissions can occur there. This should be clarified that this is after catalyst light-off, so its not really during the true cold start. So, its probably pretty reasonable to not focus too much on cold starts. Perhaps some comparison between bag 1 and bag 3 emissions for studies with FTP emissions so see how strong an effect this is.

EPA Response: We have added text to clarify that the cold-start refers to the period after the catalyst light-off.

Reviewer comment: For the 1980 and older vehicle, EPA used a simple average of 1960-1974 and 1975-1980 vehicles. EPA notes, and as expected, the contribution of these vehicles is small. Can this be quantified. For example, is the contribution less than 1% or 0.5%? It would also be interesting to at least know if the population is skewed to one of the other model group, in which case perhaps the emission rate could be population weighted. Or perhaps a discussion of what calendars EPA expects might be. For example, in Figure 6-7 pre-1980 vehicles are not even included in the oldest calendar year presented (2010), and pre-1987 vehicles are not included in the 2017 calendar year.

Section 6.1.2.2 – The EPA assumes 1981-1988 vehicles to have the same emission rates as the other pre-1996 vehicles. Its probably reasonable to make this simplification, as the inventory impact should be small. Again, it would be useful to get a context as to have small this contribution would be, say less than 0.5%, or whatever. And or that the calendar years to be modeled will likely exclude these vehicles going into the future.

EPA Response: Since MOVES models only 30 model years for each calendar year, pre-1980 vehicles are not relevant after calendar year 2010 and pre-1987 vehicles are not relevant for calendar years after 2017. For calendar year 2010, the contribution of model years 1980-1987 to total ammonia emissions is ~1% and will decrease consistently until calendar year 2017. We have added a sentence in Section 6.1.2.2 with similar information for pre-1990 vehicles and which calendar years include contributions from these vehicles.

Reviewer comment: The assumption that the E85 vehicles can be made equal to the light-duty gasoline vehicles appears reasonable. More information related to this can be found in the recent CARB E10-E15 referenced above. The CARB study showed some vehicles with differences between E10 and E15, but not consistent trends, and in some cases with larger experimental variability.

NH_3 data for light-duty diesel vehicles is pretty limited. Suarez-Bertoa et al. (references 90 and 91) show emission rates below 10 mg/mi, consistent with the use of a low fuel –based emission factor of 0.18 g/kg-fuel for diesel. UCR/CE-CERT also found emissions rates below 10 mg/mi in the CRC AVLF-17b study, provided above. I would at least include a sentence with these references in them just to have more complete coverage.

I think the suggestions are generally OK, with some possible clarification, as discussed above.

EPA Response: We have added the references suggested for E85 and light-duty diesel sections.

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?

Reviewer comment: Looking at Figure 6-3, while it does show that aging effects do seem to something that is found at many of the different sites, one other thing that it seems to show is that there are marked differences in the emission rates for different sites (sometimes more than double, especially given the log scale). The emission rates for IL_CHIC and CA_LA in particular seem to be much higher than those for the other sites. In looking at the sites themselves, does anything stand out in the locations that might be creating a bias?

EPA Response: Thank you for this question. We hypothesize that the reason these locations stand out is a combination of acceleration conditions and age of the fleet. As noted in the report, ammonia is mostly likely to formed under "rich" conditions, which are more common during higher accelerations. For example, for the 2004-2013 model years, the IL_CHIC and CA_LA sites have a mean acceleration of 0.25 mph/s and 0.8 mph/s while the OK_TULS and CO_DENV sites have a much lower mean acceleration (0.06 mph and -0.15 mph/s) ; other sites with relatively high mean acceleration like CA_SAJO (1.0 mph/s) and CA_VANU (0.33 mph/s) have a younger fleet within this MY group, likely contributing to lower NH_3 emissions.

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

Reviewer Comment: Figure 6-2 is central to the inputs into the model, so its worthwhile looking at this one a bit deeper. As a guidepost, I used 7.87 liters/100 km (see ref 87) to allow comparisons with studies reporting in units of mg/mi. Based on this, we get roughly the following for the 2004-2013 model years.

=(0.5 g/kg *(0.74 kg/L)* (7.87 liters/100 km)*(1 km/0.62 miles) = 47 mg/mi

Higher emission rates have been seen for 1990s vintage vehicles, as shown in an older Durbin et al. (2002) study, that was used extensively in the Sierra report on emission rate developments. Durbin, T. D., R. D Wilson, J. M. Norbeck, J. W. Miller, T. Huai, S. Rhee. 2002. Estimates of the Emission Rates of Ammonia from Light-Duty Vehicles using Standard Chassis Dynamometer Test Cycles. Atmospheric Environment, vol. 36, 1475-1482.

Reference 87 shows many emissions rates in a similar ballpark that seem to be in a very similar range. I have not done the unit conversion, but I am guessing that this is in the range of the values for the 2004-2013 vehicles. I think it would be worthwhile adding one sentence to the end of section 6.1.2.1 talking about the emission rates from reference 87, just to show how they compare to the emission rates shown in figure 6-2.

EPA Response: Thank you for the suggestion. We have added a sentence at the beginning of Section 6.1.2.2 (for consistency with the order of figures being discussed) comparing the average of MY 2004-2013 vehicles shown in Figure 6-2 to the value reported by Sun et al. using the conversion factors reported in that study.

Reviewer 2 Keshav S. Varde, Ph.D.

Does the report 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?

Reviewer Comment: Yes. The report has clearly identified data sources used to model NH3 emissions from light-duty vehicle (LDV) and trucks (LDT). Selected data sources are described in sufficient details for the reader to make judgement on its quality and extensiveness. Any assumptions made in the process are also identified.

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic.

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer Comment: No. The data is quite extensive and of good quality. The University of Denver (U of D) data has been cited in several publications

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

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?

Reviewer Comment: The procedure and methodology used to update NH3 emissions from LDV and LDT in the latest version of MOVES are described adequately in the report. The averaging process for earlier model year vehicles (1960-1980) is well justified while the remote sensing data used for later model years is described in details. The report provide steps taken, and in some cases, description of the steps taken for developing model inputs.

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer Comment: The tables and figures represented in the report support the assumptions made in developing the inputs.

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics?

Reviewer Comment: Adequate methods and procedures are used to validate the U of D data for LDV and LDT. The modification of the data for unit consistency is also described in the updated model. The graphical presentation of NH3 emissions for the 1981-2018 vehicle groups and the subsequent equations used to determine FER demonstrate an approach that is rooted in math/statistics and physics.

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer Comment: In general, the approaches used are good. The concern is in distinguishing the fuel use in the vehicles in the U of D remote sensing data. The data does not seem to discriminate NH3 emissions between E0, E10 and E85 fueled vehicles. The impact of this on emissions would depend on the number of vehicles with higher oxygenated fuel.

EPA Response: Thank you for this comment. Indeed, the VIN decoding method used does not differentiate between different types of gasoline. However, as mentioned by another reviewer, a recent study has not found a clear trend between NH_3 emissions and different levels of ethanol. We have added this reference to the paragraph to support our assumptions.

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?

Reviewer Comment: Most of the assumptions made to form the approaches are appropriate. The averaging of emissions for earlier model year vehicles is a reasonable and won't introduce much error since the population of these vehicles is bound to be lower compared to recent model year vehicles.

There is very little published data on nitrous acid (HONO) from diesel powered vehicles. The ratio of HONO/NOx ~ 0.8% is reasonable and has been mentioned in the literature.

It is unclear if all vehicles in the U of D data are assumed to use conventional gasoline (E10 or E0). Recent study (Suarez-Bertoa, 2015) suggests NH3 emissions for the E85 fuel may be slightly higher than the corresponding value for the E10. In addition, there is no accounting if any of the vehicles in the data sets were powered by natural gas which may emit higher levels of NH3 depending on the control system (Farren, et al, 2020). If the data couldn't discriminate between the fuels used, if any, then the report should state so or indicate the assumption made on the fuel usage.

EPA Response: Thank you for the reference suggested. As mentioned above, we cannot differentiate between different types of gasoline. However, we have added the Suarez-Bertoa 2015 reference to the E85 section to provide a contrasting point and reflect the differences obtained in current studies. As for light-duty CNG vehicles, is not possible to identify post-market changes to a vehicle as our methodology is based on VIN decoding. Furthermore, while there is uncertainty in estimates of LD CNG vehicle populations, DOE estimates they make up only about 1% of the current LD fleet. (https://afdc.energy.gov/files/u/data/data_source/10861/10861_AFV_registrations_12-16-21.xlsx)

Reviewer Comment: Likewise, it appears that Table 8-3 assumes the fuel in light-diesel powered vehicles is diesel (regular or ULSD). But, some later model diesel vehicles use biodiesel blends,

which tend to produce slightly higher NOx than that is produced by 100% diesel. The report may like to mention the type of fuel used in Table 8-3.

EPA Response: Thank you for the comment. The data comes from tunnel studies and cannot differentiate between trucks using diesel or biodiesel blends.

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

Reviewer Comment: In general, most of the model inputs are appropriate including those for LDV powered by diesel fuel. The updated report does recognize the limitations of using data from a single location, as was done using the U of D data.

EPA Response: Thank you. We note however, that the University of Denver dataset covers multiple locations across the country.

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

Reviewer Comment: Yes, based on assumptions made

EPA Response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Report #2: Exhaust Emission rates for Heavy-Duty

The changes to this report for the peer review of criteria emissions include updates to heavy-duty ammonia rates and the nitrogen oxide composition of heavy-duty vehicles, which are documented in Section 5 and Section 7, respectively.

Reviewer 1 Thomas D. Durbin, Ph.D.

Does the report 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? Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer comment:

a) For the NO2 & HONO/NOx ratio, we see many of the same studies and descriptions. Again, I have suggestions for additional data sets, as discussed below. I did not see a description of the Kurtenbach et al. (2001) study that was used for the previous MOVES model, that are largely unchanged with the newest model. Since this study is central to the factor used in the model, I believe some further description of the study is needed. It doesn't need to be too extensive, but there should be a sentence or two.

b) Several other studies being/have been conducted in California can provided some additional data in terms of heavy-duty vehicle NH3 emission rates, including the nearly completed 200 vehicle study, as well as a precursor to this study. These studies involved both UCR and WVU. While the final report for the second study is in its final stages, the other reports have been completed, and are available, and could be added to the table. From these data, it does appear that NH3 emissions for HD diesel vehicles are pretty vehicle specific, with some vehicle types showing measurable NH3 emissions, while a larger fraction of vehicles do not. These studies also provide information on both cold start and hot start emissions.

Carder, D., Gautam, M., Thiruvengadam, A., Besch, M., 2014. In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Engines. Final Report by West Virginia University for the South Coast Air Quality Management District.

Miller, J. W., Johnson, C. K., Durbin, T., Dixit, P., 2013. In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Engines. Final Report by the University of California at Riverside to the South Coast Air Quality Management District under Contract No. 11612.

For NH3 from CNG vehicles, the following studies can be used as data sources, which show higher NH3 emissions levels. Also, the current 200 vehicle study results that will be coming out shortly show much higher emission levels.

Karavalakis, G., Jiang, Y., Yang, J., Hajbabaei, M., Johnson, K., Durbin, T., 2016, Gaseous and Particulate Emissions from a Waste Hauler Equipped with a Stoichiometric Natural Gas Engine on Different Fuel Compositions, SAE Technical Paper No. 2016-01-0799, Society of Automotive Engineers, World Congress 2016.
Karavalakis, G., Hajbabaei, M., Jiang, Y., Yang, J., Johnson, K.C., Cocker, D.R.; Durbin, T.D., 2016, Regulated, Greenhouse Gas, and Particulate Emissions from Lean-Burn and Stoichiometric Natural Gas Heavy-Duty Vehicles on Different Fuel Compositions, Fuel, 175, 146-156.

EPA response:

a) We appreciate this feedback and will update the text with a clearer description of the primary source study.
b) We appreciate the references for additional sources and feedback. Due to time and resource limitations, we cannot re-analyze ammonia rates for the versions of MOVES currently under final development, but we will consider all the studies listed for future MOVES updates. In particular, we intend to use the listed studies (and any other data sources) to update CNG ammonia rates in a future version of MOVES.

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?

Reviewer comment: Overall, the description seems to be OK, within the context of the other comments provided. Tables 5-1, 5-2, and figure 5-1 are useful illustrations. Section 5-4 is a summary section, but it only includes a figure of gasoline heavy-duty vehicles, which seems odd, and figure 5-4 only shows gasoline heavy-duty vehicles.

EPA response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic. The figures in the summary section cover all fuel types.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics? Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment:

a) While data from tunnel studies can be important, in some cases, the NH3 emissions could be at very low levels, so they might be difficult to estimate.
b) Depending on the impact of CNG heavy-duty vehicles, it is suggested that information from some of the studies above would provide a better estimate than simply setting the values equal to the heavy-duty gasoline vehicles. Also, the rates as a function of model year would not be appropriate for CNG heavy-duty vehicles, as these vehicles were not equipped with stoichiometric engines until approximate 2007. Before that, the engines were lean burn, which would probably be closer to diesel vehicles.

EPA response:

a) We agree, but we have limited data available from other sources for ammonia emissions. As other sources become available, we hope to revisit the studies we used to estimate ammonia rates and the ammonia rates themselves.
b) When we update ammonia emissions for CNG vehicles, we intend to assign emission rates by model year to better capture changes in CNG vehicle technology like those the commenter describes for pre-2007 CNG vehicles.

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.

Reviewer comment: The assumption that the NH3 emission rates for heavy-duty CNG vehicles can be set equal to the heavy-duty gasoline vehicles is not one that I feel is supported by the data. In particular, CNG heavy-duty vehicles tend to operate slight richly of stoichiometric operating conditions, to achieve lower NOx emissions, as opposed to gasoline vehicles. So, the CNG vehicles generally have much higher NH3 emission rates than those shown in table Figure 5-3, including several other CE-CERT studies that are not referenced, but are listed above, and results from our upcoming 200 vehicle study.

The assumption of relatively minor idle and cold start emissions for the heavy-duty diesel that can be zeroed out for the model is probably a reasonable one, given the expected small overall impact on the inventory.

For NH3 for heavy-duty CNG, it appears that there sufficient data available in the literature that could provide for direct estimates, as opposed to using heavy-duty gasoline vehicles.

EPA response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic, beyond those expressed above. Please see EPA responses above.

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?

Reviewer comment: As discussed above, I believe the assumptions related to heavy-duty CNG being close to heavy-duty gasoline vehicles should be evaluated further. NH3 emissions from some of the UCR studies discussed above are on the order of 1.5 g/mi, so higher than the estimated used in EMFAC.

The estimates for the NO2/NOx ratios from Carder et al. are on the order of 0.18 for the SCR-equipped diesel vehicles, while those from Miller et al. (2013) are somewhat higher, at around 0.45. Carder et al. (2013) showed very low NO2/NOx ratios for CNG vehicles.

EPA response: The additional comments and notes on ammonia rates and NOx composition are interesting and helpful.

Reviewer 2 Keshav S. Varde, Ph.D.

Does the report 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? Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer comment: Yes. The report lists several data sources for the NH3 emissions from heavy-duty (HD) diesel vehicles. It details the year and the location where the data was collected, the number of vehicles involved and the vehicles' after-treatment technologies, etc., to give the reader a general view of the quality, quantity and representativeness of the data. The data is very comprehensive

EPA response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic.

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?

Reviewer comment: The procedure and analytical methods described in the report provide adequate information to the reader to understand the steps taken during the process to develop the model inputs. Most of the assumptions made during the process are implied in the procedure. The tables have detailed information on the vehicles and show statistical spread in the values of NH3 emissions rate by exhaust after-treatment technology. The graphical presentation is certainly helpful.

EPA response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics? Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer comment: The data used in developing NH3 emissions rate (Preble, et al, 2019) involves snapshot of exhaust analysis including NH3. It is converted to emissions rate through the use of fuel consumption rate described in the earlier part of the report. It would be helpful if the fuel consumption rate is referenced here.

EPA response: This is useful feedback. We will try to include fuel consumption data or figures in the discussion of fuel-specific emission rates in future versions of this report.

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.

Reviewer comment: The assumptions made by EPA in cases where the data is scant are quite valid.

EPA response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

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?

Reviewer comment: The model inputs, derived from the actual measurements or assumed based on the vehicles operating conditions, model year and the after-treatment technology are appropriate and consistent with the chemical and physical processes involved in the on-road vehicles.

EPA response: The reviewer did not have any criticism, recommendation, or indicate any areas of improvement on this topic

Report #3: GHG & Energy Consumption Rates

This report describes the energy and greenhouse gas (GHG) rates in MOVES and documents the data sources and analyses we used to develop the energy and greenhouse gas emission rates. The section we sent for review is section 3.b Nitrous Oxide Emission Rates – Diesel Vehicles.

Reviewer 1 Thomas D. Durbin, Ph.D.

Does the report 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? Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer Comment: reviewer agreed section 1.1.2 is sufficient to give the reader a feel for the data but not being overwhelming. For section b.1 Light-duty diesel, the reviewer commented it's hard to tell how much data is incorporated into the 1990-2006 GHG report. Graham et al. listed later has some more recent data that is a bit newer. The reviewer also provided some studies that might be useful for us to look into, including a heavy duty N2O study by California, light duty diesel vehicle study by Graham et al., a review study from Hoekman et al., etc .

EPA Response: The recommended references and data sources will be considered as potential data sources for our next round of updates for N_2O 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?

Reviewer Comment: Things are reasonably clear with some exceptions. The paragraph below table 3.4 references a 2016 Preble study, which should be 2019.

One thing that is worth discussing is in going from the LDV section, where emissions are given in g/mi to the heavy-duty section where there are fuel-based emission factors and bins. Some additional information should be provided to better differentiate between the methods.

Our recent data does suggest higher cold start N2O emissions for heavy-duty vehicles. Its probably a pretty small contribution in the broader scheme, as suggested in the section, so its probably not worth making updates at this point, but these data should be considered for the next version of the model.

EPA Response:

We have corrected the citation for Preble et al.

Diesel exhaust aftertreatment technologies are known to increase N_2O from diesel trucks. For MOVES3.R1, we updated heavy-duty diesel N_2O emission rates. Since net emissions for gasoline and light-duty diesel vehicles are expected to remain relatively low (see Figure 3-1, Figure 3-2, Figure 3-3, and Figure 3-5), we did not update those rates and they continue to be based on the older data and methodology described in the sections above. We have added text to clarify this point.

We will consider the data on cold start N_2O rates for future MOVES updates as suggested.

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? 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?

Reviewer Comment: More information on cold start heavy-duty N2O emissions should be available shortly, and should be added to the next version of the model. As the overall cold start contribution is probably small for heavy-duty vehicles, this is probably adequate for the time being.

As discussed above, the data inputs for the light-duty vehicles could be improved based on an additional evaluation of the literature. For heavy-duty vehicles, there is data that is nearly published that can be used to update the N2O emissions rates for running emissions and cold starts.

EPA Response: We are looking forward to seeing the published article about heavy-duty N_2O rates, and we would like to conduct more literature review to improve our light-duty N_2O rates as resources allow.

Reviewer 2 Keshav S. Varde, Ph.D.

The reviewer provided mostly positive feedbacks, that the report cites data sources to allow the reader to form a comprehensive view of the quality, quantity and representativeness od the data. The data is based on a large inventory of information, collected over a period of several years, for light and heavy-duty diesel powered vehicles. The reviewer showed understanding of while there some differences in the N2O emission rates, these differences are not unusual and come about due to operating conditions as well as the state of the exhaust after-treatment system and its control.

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.

Reviewer Comment: The assumptions made in the report are very reasonable. There is hardly any reliable published data on N2O emissions from diesel or compressed natural gas (CNG) powered vehicles at idle.

It would be desirable to include emission rate at idle if and when the data becomes available; its contribution may alter the greenhouse gas (GHG) emission, given the fact that heavy-duty diesel powered vehicle tend to idle for extended periods.

EPA Response: We agree that it would be desirable to include emission rates at idle if and when the data becomes available.

Report #4: Evaporative Emissions from Onroad Vehicles

This report describes how MOVES models evaporative emissions from onroad vehicles including emissions from gasoline and E85 vehicles during operation and parking, and from gasoline, E85 and diesel vehicles during refueling.

For MOVES3.R1, we updated the updated the algorithm and underlying data that estimates evaporative emissions during refueling to better account for functioning Onroad Refueling Vapor Recovery control. This update also repairs a small error in the effect temperature has on refueling emissions that was present in previous versions of MOVES.

After the report was reviewed, we found a documentation error in Equation 13, describing the calculation of uncontrolled vapor emissions from refueling. The actual equation in MOVES has not changed from previous versions of MOVES, but the documentation for prior versions and the draft report shared with peer reviewers mistakenly showed a linear equation rather than the actual exponential one. While the parameters in the equation are similar and reviewer comments on the parameter appropriateness may still be valid, the MOVES use of the exponential equation has not been subject to peer review.

Reviewer 1 Thomas D. Durbin, Ph.D.

Does the report 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?

Reviewer Comment: It appears that there are some solid recent data for this portion of the modeling, with the studies for references 42, 43, and 44 all being 2021 or newer. While some of the other studies are older, a number deal with foundational items that should not change dramatically with age, such as temperatures between tank and dispensed fuel (41), vapor vs. RVP (39), and temperature of dispensed fuel (40). It is also good that there is now a value for ORVR vehicles of 0.0361 g/gal, based on IUVP data.

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer Comment: The data sources for this part of the model appear to be good.

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?

Reviewer Comment: There are some parts of the discussion that could be improved.

2nd paragraph – It talks about MOVES not accounting for any interaction between ORVR and dispensing stations. Its just unclear what this means. And the next sentence about the technology adjustment being the same for all locations. Perhaps these could both be included later where they are discussed specifically.

Section 3.6.1 equation 13. DT is defined as temperature difference between tank and dispensed … Presumably this is dispensed gasoline temperature.

Section 3.6.2 – It is not really clear why spillage is a big function of Stage II and ORVR. Presumably this is the droplets that are dropped when the nozzle goes between the pump and the gas fill location on the car. It seems like this could be defined just to make it clearer.

EPA response: For each of these comments we have revised the report text to provide more detail. As noted above, we have replaced Equation 13 and re-written this section for clarity and accuracy.

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer Comment: I like table 26, which shows the phase in of ORVR.

Where possible, it seems like it would be useful to include descriptive information about how widely the parameters vary. For example, the ambient temperatures being between 45 and 90F. The -0.68%/year, and the 0.0361 g/gal. With that context, it seems like it would be useful for the reader to get an idea for how wide a range there is for "E" in equation 13 (displaced vapor) and the refueling displacement vapor loss in equation 14.

EPA response: As noted above, we have replaced Equation 13 entirely. We have added text explaining the likely range of values for uncontrolled vapor displacement (equation 13) and provided more detail on the parameters used in calculating controlled emissions (equation 14).

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics?

Reviewer Comment: Overall, the principles used appear to be sound, as refueling losses are going to be function of things like temperature and RVP, with technology adjustments for ORVR and Stage II, that appear to be adequately considered.

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer Comment: The approach taken appears to be reasonable.

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?

Reviewer Comment: It looks like EPA has done a good job in expanding the data used in this section, with data from IUVP testing and a recent high evaporative emission field study, as well as estimates of new estimates for ORVR systems.

If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.

Reviewer Comment: The data sources and associated assumptions appear to be reasonable.

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?

Reviewer Comment: The inputs, based on temperature and RVP, with technology adjustments for ORVR and Stage II, that appear to be appropriate.

One item that might be worth considering is that some areas where pollution can be pretty high may have temperature greater than 90F, and that the vapors under those conditions might have a greater impact on high pollution events.

EPA response: We have added a footnote explaining this limitation in using MOVES estimates of dispensed fuel temperature (and thus the difference between dispensed temperature and vehicle tank temperature) in areas with sustained high temperatures.

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

Reviewer Comment: Yes. The model inputs appear to be consistent with the literature. With EPA having some great sources of data in the IUVP data that would not otherwise be obtained through more traditional studies.

Reviewer 2 Keshav S. Varde, Ph.D.

Does the report 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?

Reviewer Comment: The report describes data sources that are used to develop evaporative emissions from on-road vehicles. It includes vapor recapturing program at the pump (referred to as Stage II vapor control). The report does identify several sources (data and/or tables) that are used to estimate displaced vapor. While the report relies on data from the state and local authority, it is aware some of the state or local database may not be up to date due to changes and/or termination of some Stage II programs. The data used for the onboard refueling vapor recovery program (ORVR) does account for the phase-in by model year and the type of the vehicle

Can you recommend alternate data sources that might better allow the model to estimate national or regional default values?

Reviewer Comment: The data sources used in the program capture available information quite adequately

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?

Reviewer Comment: In general, the methods and procedures provide adequate information to the reader on the steps taken while developing the model inputs. The accounting for spillage for Stage II and ORVR type controls is described clearly enough for readers to understand (those who are familiar with evaporative losses)

Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Reviewer Comment: The tables are clearly listed (and included) in the report so the reader can comprehend the approaches used in the process.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics?

Reviewer Comment: The equation (equation 13) used to estimate displaced vapor has appropriate parameters such as Reid vapor pressure (RVP), temperature of the dispensed gasoline, etc. A study by Wade-Reddy (SAE Trans, 1986) using detailed chemical kinetics showed the tank vapor formation has very similar parameters as those used in equation (13). It is

consistent with chemical, engineering, and mathematical aspects of the process. The procedure is clear and states specific equations used to arrive at the variables

EPA response: As noted above, we have corrected Equation 13 to reflect the equation applied in MOVES, but the correct version uses the same parameters. The exponential form of the correct equation is similar to the Wade-Reddy equation.

Can you suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs?

Reviewer Comment: While the methods and approaches are appropriate, it might be helpful to the reader if the report addressed the following:

(a) Does the estimated vapor loss account for the elevation?

(b) Is it assumed that the vapor storage system is unsaturated?

(c) Is there an assumption that there is no difference in fuel temperature between a closed and open fuel injection system?

EPA response: We have added text to explain that the refueling calculations are fairly simple and do not account for altitude, saturation of the vapor storage system, or differences in vehicle fueling designs.

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?

Reviewer Comment: Yes, the assumptions made are appropriate based on when the data was obtained

If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.

Reviewer Comment: It may be necessary to visit the diurnal temperatures used in the study.

EPA response: As noted above, we have added a footnote explaining that the lack of data for dispensed fuel temperature at high ambient temperatures is a limitation in our modeling.

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?

Reviewer Comment: The inputs to the model seem very reasonable given the complexity of thermochemical reactions that occur in the fuel tank. Most of the model inputs have been derived from physical and/or chemical phenomena

Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

Reviewer Comment: Yes, they are.