

Federal Advisory Committee Act
Clean Air Act Advisory Committee

**Mobile Sources Technical Review Subcommittee (MSTRS)
MOVES Review Work Group: Meeting Summary**

April 10, 2019
U.S. EPA Office of Transportation & Air Quality
2000 Traverwood Drive
Ann Arbor, MI 48105

Welcome from the Chairs

Dr. Matthew Barth and Ms. Megan Beardsley welcomed the Clean Air Act Advisory Committee (CAAAC), Mobile Sources Technical Review Subcommittee (MSTRS) MOVES Review Work Group to the meeting. Ms. Beardsley presented the meeting agenda (see Table 1).

**Table 1. MOVES Review Work Group Meeting Agenda:
April 10, 2019 (2 pm to 4 pm)**

Topic
Welcome from the Chairs
Member Roll Call
General Announcements
Presentations: <ul style="list-style-type: none">• Updates to EPA’s Motor Vehicle Emissions Simulator (MOVES) – Highlights from CRC Real World Emissions Workshop• Updates to “High-Power” Emission Rates and Start Deterioration for Light-Duty Vehicles Update: Revising Start/Soak Relationships for Light-Duty Gaseous Emissions• Updates to MOVES Heavy-Duty Running Exhaust Rates: Diesel, Gasoline, and Natural Gas• Modeling of Gliders in MOVES
Future Meetings/Wrap-up

Member Roll Call

Ms. Beardsley conducted a Work Group member roll call. A list of Work Group members and others in attendance is presented in an Attachment to these meeting minutes.

General Announcements

Dr. Sarah Roberts made general announcements regarding meeting procedures, including how participants should signal when they had questions (i.e., by using the raised hand feature in Adobe Connect). Dr. Roberts stated that the meeting minutes will be submitted to the Work Group members for review before posting to the website and that any additional questions about the technical content of today's presentations should be sent to her at her e-mail address: Roberts.Sarah@epa.gov.

Presentation: Updates to EPA's Motor Vehicle Emissions Simulator (MOVES) – Highlights from CRC Real World Emissions Workshop – Presented by Megan Beardsley, U.S. EPA

The next major version of MOVES will include new data, newer rules, improved functionality and performance and additional features. The next version release data is still to be determined but will be in 2020 at the earliest. Activity improvements for the next MOVES version include updated user inputs for starts and idling and user inputs for off-network idle, which allows users to input total idle fraction by vehicle type, month or day. Other vehicle population and activity updates include historical and projection data for national VMT and vehicle populations, national age distribution, vehicle weights and other vehicle characteristics. There are several major changes planned for both light-duty and heavy-duty on-road vehicles, some of which are expected to increase the model's estimates of emissions and some of which are expected to decrease the model's estimates of emissions.

There is also continuing work on a comprehensive update to the Nonroad portion of the model. The initial focus is on diesel engines--including updating population and activity data--and also redesigning the model structure. In addition, more real-world activity data is being gathered for inclusion in the Nonroad model.

Presentation: Updates to “High-Power” Emission Rates and Start Deterioration for Light-Duty Vehicles– Presented by Claudia Toro, ORISE participant & James Warila, U.S. EPA

Part 1 – Updates to “High-Power” Running Emission Rates

As part of the EPA's ongoing effort to validate the MOVES model, they have evaluated default model inputs using newer data or assumptions. This presentation focuses on these efforts for high-power light-duty running emission rates and light-duty start emissions. Previous NO_x evaluation efforts have shown that MOVES compares well with remote sensing (RS) data when modeled at the project scale using location-specific inputs, but MOVES overestimates emissions modeled at the national scale using inputs from the National Emissions Inventory (NEI). One of the reasons for this outcome was that the NEI includes higher power operating modes than represented in the RS data, and so the EPA focused on evaluating high power operating mode emission rates. To evaluate power trends, they used data collected in two studies using portable emissions measurement systems (PEMS), with the goal of reassessing the shapes of vehicle-

specific power (VSP) trends from low to high power. In comparing the MOVES estimated emissions with the PEMS data, the MOVES NO_x-VSP and other gaseous pollutant-VSP trends were steeper than the PEMS data for cars and trucks, with the difference being more pronounced for trucks. As a result of this study, the EPA plans to scale rates uniformly across the VSP trend to more accurately estimate emissions at high power rates. This change will affect all gaseous pollutants representing vehicles under National Low Emission Vehicle (NLEV), Tier 2 and Tier 3 standards (model years 2001 and later, inclusive).

Part 2 – Updates to Deterioration Trends for Start Emission Rates

There is currently only sparse data regarding whether light duty vehicle start emissions increase with increasing vehicle age (i.e., start deterioration). One relevant data source is the In-Use Verification Program (IUVP) run by manufacturers that aims to verify that following sale, vehicles continue to meet standards during their regulatory useful lives. In this program, vehicles are recruited from the public, and emissions are measured on certification cycles (including FTP and US06), and FTP data, by phase, can be used to estimate start deterioration. Based on this data, it appears that deterioration occurs for both starts and running. In MOVES, the deterioration for NO_x starts is based on the deterioration trend for running emissions. Based on the study of the IUVP data, which shows that starts do deteriorate, but at a lower relative rate than running emissions, the EPA plans to apply a reduced deterioration trend to NO_x start emissions. This will apply passenger cars, light-duty trucks and heavy-duty gasoline vehicles in all model years.

Part 3 – Emissions Impact

The updated start deterioration trend is expected reduce estimated emissions across all calendar years. The revised high-power emissions rates are expected to reduce emissions more in future years because the high-power emissions were a larger fraction of total emissions for future vehicles. The updates are expected to result in lower emission inventories for gaseous criteria pollutants across all years.

Discussion

Ms. Julie McDill asked whether the rate mode was displayed in the presentation, particularly regarding the information for MOVES compared to RS data for NO_x emissions. It was clarified that rate mode was not displayed, but that the national scale and project scale results were shown. Ms. McDill commented that it would be helpful to also see the rate mode results.

Ms. Susan Collett remarked that a study evaluated emissions in two tunnels and was published recently, measurements from the Hong Kong study agreed well with the MOVES model results. However, the Baltimore tunnel showed a large discrepancy in results compared to MOVES.

Post Meeting correction: The study is available on the HEI webpage, here: <https://www.healtheffects.org/publication/real-world-vehicle-emissions-characterization-shing-mun-tunnel-hong-kong-and-fort>. The researchers compared the California Air Resources Board vehicle emissions model, EMFAC, to the Shing Mun Tunnel in Hong Kong, and to the Fort McHenry Tunnel in Baltimore to the MOVES model.

Dr. Barth noted that the MOVES to PEMS comparison was using a single PEMS study done in North Carolina. He suggested that additional PEMS data could be used to validate or correct the entire model. Dr. Chris Frey commented that additional data could be used to verify the North Carolina data. He noted that the North Carolina dataset was used for MOVES because it is the largest dataset that is publicly available.

Ms. McDill mentioned that she would be interested to know what the data sources were for prior MOVES versions.

Dr. Frey asked whether MOVES was predicting the mean or median of emissions for deterioration. Mr. James Warila replied they did a log-linear fit to passenger cars and each truck class and tested for differences in log-linear slope. Since the differences were not significant, a uniform slope was used for all truck classes. Also, since a uniform variance was estimated across the entire trend, comparisons at the mean would be equivalent to those at the median (geometric mean). Dr. Frey asked whether additional review was planned. Mr. Warila replied that the underlying analyses are described in the report for light-duty rates used in the model.

Mr. Frey noted that Tier 2 vehicles were included in the analysis and asked whether the vehicles with more stringent standards had higher deterioration rates. Mr. Warila replied that it the opposite seemed to be the case- that similarity in log-linear trends among vehicles under various standards implies that trends in absolute emission rates became more gradual, not steeper.

Mr. Frey commented that some studies have concluded that MOVES overpredicts NO_x emissions, and he asked whether the planned revisions to MOVES bring the model-predicted emissions in line with what those studies have claimed are the actual emissions levels. Mr. Warila replied that the revisions discussed in the current presentation do result in reductions in NO_x emissions. However, these updates do not provide a definitive resolution to this issue raised by Dr. Frey, and the EPA is still looking for other causes of the potential overprediction of emissions.

Presentation: Updates to MOVES Heavy-Duty Running Exhaust Rates: Diesel, Gasoline, and Natural Gas – Presented by Gurdas Sandhu, ORISE participant

This presentation focuses on running exhaust emission rates for model year 2010 and newer diesel, gasoline, and compressed natural gas (CNG) heavy-duty vehicles and the resulting impact on the emissions inventory. The initial part of the presentation covered recent changes to the scaling factor (f_{scale}), which is used in the scaled tractive power (STP) equation to arrive at operating mode (OpMode) based rates. The diesel and CNG emission rates are based on the manufacturer-run heavy-duty in-use testing (HDIUT) data. The gasoline emission rates are based on data from a study conducted at the EPA labs in Ann Arbor. Emission rates for nitrogen oxides (NO_x), particulate matter (PM_{2.5}), carbon dioxide (CO₂), carbon monoxide (CO), and Total Hydrocarbons (THC) were presented on a gram/mile basis for calendar year 2035, showing the effect of age on model years 2035 back to 2010. The gram/mile comparison of new rates versus base rates in MOVES vary significantly based on fuel type, vehicle class, and pollutant. Further,

the impact of the new rates on the emissions inventory varies based on the “domain” defined by a combination of fuel type, process type, and vehicle type. The emissions impact presented here are for only the rates update covered in this presentation and do not reflect the effect of other updates to the MOVES model.

For diesel, the emission rates vary between model years 2010 to 2015 based on the production volume mix between engines with varying emissions levels. Overall, when comparing at the total onroad emissions level, the new diesel rates lead to large increase in future NO_x emissions, moderate decrease in PM_{2.5} emissions, insignificant changes to CO₂ emissions, moderate increase in CO emissions, and small decrease in THC emissions.

For heavy-duty gasoline vehicles, at the total onroad emissions level, the new rates lead to small decreases in future NO_x and PM_{2.5} emissions and small increases in future CO₂, CO, and THC emissions.

For heavy-duty natural gas vehicles, the new g/mile NO_x rates are lower, CO₂ rates are comparable, and PM_{2.5}, CO, and THC rates are significantly higher.

Discussion

In response to a question about why there are drops or jumps in emissions in certain years, Dr. Gurdas Sandhu explained that there is a jump in NO_x emissions around 2010 due to the MOVES update, whereas pre-2010 emissions were not updated. There is variability in the rates between model years 2010 and 2015 due to differences in engine production volumes. For CO₂, there are further reductions in rates due to the Heavy-Duty Greenhouse Gas Phase 1 and Phase 2 rulemakings.

Mr. Jeremy Heiken asked whether there was any update to the heavy-duty peer review. Ms. Beardsley responded that there was not an update yet, but the EPA plans to have further peer review conducted.

Mr. Heiken commented, regarding NO_x emissions, that the loss in NO_x control effectiveness is related to the location of the vehicles. He noted that there is more loss in urban areas where there is greater stop and start activity and lower-speed travel. Dr. Sandhu noted that this effect is being captured through the operating mode rates. Mr. Heiken replied that a vehicle could be in one operating mode bin, but that vehicle would have different emissions over time in an urban versus a rural setting due to the stop and go nature of urban travel. Ms. Beardsley noted that the emission rates in MOVES capture a real-world mix of urban and rural driving at each vehicle speed.

Mr. Andrew Eilbert suggested that in-use data for previous model years could be reviewed to determine whether the “jump” in emissions in 2010 is real is or just an artifact from the update. Dr. Sandhu remarked that this had been considered, but due to current resource availability, there is currently not a plan to do an analysis.

Mr. Andy Burnham asked whether the THC emissions from CNG trucks was speciated and whether methane data was collected for the vehicles. Dr. Sandhu replied that these activities have not been conducted yet.

Mr. Andrew Eilbert asked whether the CNG rates for vehicle regulatory classes other than heavy-heavy-duty (HHD) had been included. Dr. Sandhu responded that the only data available was for the HHD classes, and they will be using the rates for HHD and applying those rates to the other classes.

Mr. Eilbert asked whether the pre-2010 rates for compressed natural gas (CNG) buses were based on direct second-by-second measurement of CNG or gasoline medium-heavy duty vehicles. Dr. Sandhu replied that MOVES2014 does not have any rates based on direct second-by-second data from CNG vehicle measurements, and all the CNG rates are based on initial rates from gasoline vehicles that are scaled using cycle average emissions of CNG vehicles and CNG engine certification data. He noted that the June 2017 presentation given to the MOVES Review Work Group explains how the EPA plans to group the CNG vehicles.

Presentation: Modeling of Gliders in MOVES – Presented by Jaehoon Han, U.S. EPA

Glider vehicles are vehicles with an old powertrain (engine, transmission and/or rear axle) combined with a new chassis and cab assembly. Most gliders are Class 8 heavy-duty vehicles and typically use remanufactured engines from before 2001. Currently MOVES does not account for gliders, and the EPA is planning on including them in the next version of MOVES. To add them in, a new regulatory class was created (ID:49) within source types 61 and 62. Based on comparison of MOVES rates to EPA glider testing data, the exhaust emission rates for THC, CO, NOx and PM are set to be equal to the MY2000 HHD rates. Glider vehicle characteristics are assumed to be the same as the new (non-glider) HHD fleet. Glider sales are estimated based on the production data received from manufacturers. The fraction of diesel trucks that are gliders is less than 2% for all calendar years. The contribution from gliders to the emissions inventory is dependent on planned MOVES updates for heavy-duty emission rates, populations and activity as well as the potential reconsideration of the glider rule.

Discussion

Mr. Joe Jakuta asked whether gliders would be included in MOVES as a new source type. Mr. Jaehoon Han clarified that these would not be a new source type but are included as a new regulatory class (ID:49) for the existing sourcetypes 61 and 62.

Mr. Chris Frey commented that he has seen estimates that say if gliders were 3% of the heavy-duty population, they would contribute 5% to all NOx emissions. He asked if anyone else had seen data suggesting similar contributions to emissions. Mr. Han replied that it was a bit too early to quantify glider emissions and their relative contributions to emissions, but the EPA will soon be performing that analysis.

Dr. Barth asked about the source of the data for gliders. Mr. Han responded that the EPA has population data from the manufacturers, and the estimated emission rates are based on the EPA's glider testing data.

Wrap-Up

In closing, Dr. Roberts informed the meeting attendees that the next meeting will likely be in September, but a specific date has not yet been set. Dr. Roberts also noted that Work Group members are invited to give presentations that might help the EPA shape the MOVES model. Anyone interested in presenting at the next meeting should submit an abstract and title to Dr. Roberts.

Ms. Beardsley thanked the meeting attendees for their participation.

A full list of participants is provided as an attachment to this summary. Copies of the presentations given during this meeting will be available at <https://www.epa.gov/moves/moves-model-review-work-group>.

Attachment – Work Group Meeting Attendance List

April 2019 MOVES Review Work Group: Member Attendees

Name	Home Organization	Representing Organization
Giedrius Ambrozaitis	Alliance of Automobile Manufacturers	Alliance of Automobile Manufacturers
Matt Barth	University of California, Riverside (CE-CERT)	University of California, Riverside (CE-CERT), Work Group Co-chair
Megan Beardsley	U.S. Environmental Protection Agency (EPA)	EPA; Work Group Co-Chair
Susan Collet	Toyota	Coordinating Research Council (CRC)
David D’Onofrio	Atlanta Regional Commission	Association of Metropolitan Planning Organizations (AMPO)
Chris Frey	North Carolina State University	North Carolina State University
Mike Geller	Manufacturers of Emission Controls Association (MECA)	Manufacturers of Emission Controls Association (MECA)
Gil Grodzinsky	Georgia Department of Natural Resources	Association of Air Pollution Control Agencies (AAPCA)
Cecilia Ho	Federal Highway Administration (FHWA)	Federal Highway Administration (FHWA)
Britt Holmen	University of Vermont	University of Vermont
Mark Janssen	Lake Michigan Air Directors Consortium (LADCO)	Lake Michigan Air Directors Consortium (LADCO)
Chris Kite	Texas Commission on Environmental Quality	Association of Air Pollution Control Agencies (AAPCA)
Jim Kliesch	Honda	Honda
David Lax	American Petroleum Institute (API)	API
Lubna ShoaiB	East-West Gateway Council of Governments	Association of Metropolitan Planning Organizations (AMPO)
Chris Voigt	Virginia Department of Transportation	Amer. Assoc. of State Highway and Transportation Officials (AASHTO)
Dale Wells	Colorado Department of Public Health and Environment	National Association of Clean Air Agencies (NACAA)
Chris Wolfe	Environmental Defense Fund (EDF)	Environmental Defense Fund (EDF)
Wei Zhang	Idaho Department of Environmental Quality	NACAA

April 2019 MOVES Review Work Group: Other Attendees

Name	Home Organization	Representing Organization
Marc Bennett	Massachusetts Department of Environmental Protection	Massachusetts Department of Environmental Protection
Charles Bernhard	Iowa Department of Transportation	Iowa Department of Transportation
Molly Birnbaum	Alaska Department of Environmental Conservation	Alaska Department of Environmental Conservation
Daniel Bizer-Cox	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Kevin Black	Federal Highway Administration (FHWA)	Federal Highway Administration (FHWA)
And Bollman	North Carolina Department of Environmental Quality	North Carolina Department of Environmental Quality
Chris Bovee	Wisconsin Department of Natural Resources	Wisconsin Department of Natural Resources
Chris Boyd	Shelby County Health Department	Shelby County Health Department
Jim Boylan	Georgia Department of Natural Resources	Georgia Department of Natural Resources
Kevin Briggs		
Andy Burnham	Argonne National Laboratory	Argonne National Laboratory
Craig Butler		
Yuli Chew	New Jersey Department of Environmental Protection	New Jersey Department of Environmental Protection
David Choi	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Ying-Tzu Chung	Michael Baker International	Michael Baker International
Marc Corrigan	Tennessee Department of Environment and Conservation	Tennessee Department of Environment and Conservation
Susanne Cotty	Pima Association of Governments	Pima Association of Governments
Angela Cullen	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Robert d'Abadie	Michael Baker International	Michael Baker International
Tom Darlington	Air Improvement Resource, Inc.	Air Improvement Resource, Inc.
Matt Davis	North Carolina Department of Environmental Quality	North Carolina Department of Environmental Quality
Laurel Driver	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Tom Dvorak	New Jersey Department of Environmental Protection	New Jersey Department of Environmental Protection
Andrew Eilbert	U.S. Department of Transportation	U.S. Department of Transportation
Alison Eyth	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Sara Forestieri	California Air Resources Board (CARB)	California Air Resources Board (CARB)
Janice Godfrey	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Jaehoon Han	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Tom Hanf	Michigan Department of Transportation	Michigan Department of Transportation
Jeremy Heiken	Oak Leaf Environmental	Oak Leaf Environmental

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Name	Home Organization	Representing Organization
Joe Jakuta	DC Department of Energy and Environment	DC Department of Energy and Environment
Dennis Kahlbaum	Air Improvement Resource, Inc.	Air Improvement Resource, Inc.
David Kall	Federal Highway Administration (FHWA)	Federal Highway Administration (FHWA)
Miles Kemp	Georgia Department of Transportation	Georgia Department of Transportation
Byeong-Uk Kim	Georgia Environmental Protection Division	Georgia Environmental Protection Division
Dorian Kvale	Minnesota Pollution Control Agency	Minnesota Pollution Control Agency
Steve Lachance	Michigan Department of Environmental Quality	Michigan Department of Environmental Quality
Sonya Lewis-Cheatham	Virginia Department of Environmental Quality	Virginia Department of Environmental Quality
KJ Liao	Georgia Environmental Protection Division	Georgia Environmental Protection Division
Natalie Liljenwall	Oregon Department of Transportation	Oregon Department of Transportation
Jin-Sheng Lin	Virginia Department of Environmental Quality	Virginia Department of Environmental Quality
Deborah Liu	Shelby County Health Department	Shelby County Health Department
Jeff Long	California Air Resources Board (CARB)	California Air Resources Board (CARB)
Julie McDill	Mid-Atlantic Regional Air Management Association	Mid-Atlantic Regional Air Management Association
Hyunsoo Noh	Pima County Association of Governments	Pima County Association of Governments
Jinchul Park	Metropolitan Washington Council of Governments	Metropolitan Washington Council of Governments
Jane Posey	Metropolitan Washington Council of Governments	Metropolitan Washington Council of Governments
Steve Potter	Connecticut Department of Energy and Environmental Protection	Connecticut Department of Energy and Environmental Protection
Ivan Racic	Arizona Department of Transportation	Arizona Department of Transportation
Vikram Ravi	Washington State University	Washington State University
Brian Rivera		
Sarah Roberts	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Gurdas Sandhu	U.S. Environmental Protection Agency/ORISE	U.S. Environmental Protection Agency/ORISE
Ken Santlal	Massachusetts Department of Environmental Protection	Massachusetts Department of Environmental Protection
Jolyon Shelton	Delaware Dept. of Natural Resources and Environmental Control	National Association of Clean Air Agencies (NACAA)
Kira Shonkwiler	Colorado Department of Public Health and Environment	Colorado Department of Public Health and Environment
James Smith	Tennessee Department of Environment and Conservation	Tennessee Department of Environment and Conservation
Collin Smythe	Vermont Department of Environmental Conservation	Vermont Department of Environmental Conservation

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Name	Home Organization	Representing Organization
Matt Solomon	Northeast States for Coordinated Air Use Management	Northeast States for Coordinated Air Use Management
Darrell Sonntag	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Glade Sowards	Utah Department of Environmental Quality	Utah Department of Environmental Quality
Lesley Stobert	SC&A, Inc.	EPA Contractor
Brian Sullins	Alabama Department of Environmental Management	Alabama Department of Environmental Management
Vivek Thimmavajjhala	North Central Texas Council of Governments	North Central Texas Council of Governments
Ted Thrasher	U.S. Department of Transportation	U.S. Department of Transportation
Brian Timin	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Claudia Toro	U.S. Environmental Protection Agency/ORISE	U.S. Environmental Protection Agency
Chris Trostle	Pennsylvania Department of Environmental Protection	Pennsylvania Department of Environmental Protection
Brian Trowbridge	Pennsylvania Department of Environmental Protection	Pennsylvania Department of Environmental Protection
Marcus Tutt	New Jersey Department of Environmental Protection	New Jersey Department of Environmental Protection
Steven VanderGriend	Urban Air Initiative	Urban Air Initiative
Shaun Vozar	Allegheny County Health Department	Allegheny County Health Department
James Warila	U.S. Environmental Protection Agency	U.S. Environmental Protection Agency
Debbie Wilson	Mid-Atlantic Air Management Association (MARAMA)	Mid-Atlantic Air Management Association (MARAMA)
Craig Woleader	Massachusetts Department of Environmental Protection	Massachusetts Department of Environmental Protection
Michael Woodman	Maryland Department of the Environment	Maryland Department of the Environment
Tao Zeng	Georgia Environmental Protection Division	Georgia Environmental Protection Division
Wei Zhang	Idaho Department of Environmental Quality	Idaho Department of Environmental Quality