



MEMORANDUM

TO: Metropolitan Washington Air Quality Committee – Technical Advisory Committee
FROM: Dusan Vuksan, TPB Transportation Engineer
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SUBJECT: MOVES3 Model Sensitivity Testing
CC: Kanti Srikanth, Transportation Staff Director
DATE: September 12, 2022

BACKGROUND

The U.S. Environmental Protection Agency (EPA) is tasked with development and maintenance of mobile emissions models that are used to forecast on-road, transportation-sector tail-pipe emissions for the criteria pollutants and greenhouse gases (GHGs). The model, called MOTO Vehicle Emissions Simulator, or MOVES, is used to estimate criteria pollutant emissions for state implementation planning (SIP) and air quality conformity (AQC) analyses. In 2017, the Metropolitan Washington Air Quality Committee (MWAQC) developed a maintenance SIP and the associated motor vehicle emissions budgets (MVEBs) for the 2008 Ozone National Ambient Air Quality Standards (NAAQS) using the MOVES2014a model. Most recently, in June 2022, the National Capital Region Transportation Planning Board (TPB) adopted the AQC analysis of the 2022 Update to the Visualize 2045 Long-Range Transportation Plan (LRTP), which relied on a very similar MOVES2014b model to estimate mobile emissions (identical to MOVES2014a for the on-road estimates in our region). The EPA released a more major update to the MOVES2014b model, MOVES3, in January 2021. All AQC analyses that begin after early January of 2023 (the end of a two-year grace period) will need to be conducted using MOVES3.

Given that the currently applicable MVEBs and the most recent air quality conformity analyses were conducted using the MOVES2014 model family, TPB staff have conducted a preliminary sensitivity test using the MOVES3 model to assess impacts of the new model on the emissions estimates from the most recent 2022 Update to Visualize 2045 LRTP air quality conformity analysis (i.e., MOVES3 versus MOVES2014b comparison). This technical memorandum documents the key findings. The memo also includes recommended next steps in regional air quality (SIP) and transportation planning (AQC) related to using the new model.

MOVES3 MODEL FEATURES AND EXPECTATIONS

Upon release of the MOVES3 model, EPA provided model documentation and shared information via webinars. Some of the main features of the MOVES3 model include:^{1 2}

- Updated heavy-duty (HD) diesel and compressed natural gas (CNG) emission running rates based on manufacturer in-use testing data from hundreds of HD trucks, and updated HD gasoline emission rates based on instrumented vehicles
- Updated light-duty (LD) emission rates for hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx) based on over 100,000 emission measurements and updated LD particulate matter rates, incorporating new data on Gasoline Direct Injection (GDI) vehicles
- Updated LD and HD start emission rates based on test data
- Updated gasoline and diesel fuel parameters to incorporate data from EPA fuels compliance testing
- Updated vehicle activity, such as vehicle start and idling activity patterns, based on real-world data
- Improved accounting of vehicle starts, long-haul truck hotelling,³ and off-network idling
- Increased fuel consumption (thus higher CO2 emissions) to account for the Safer Affordable Fuel-Efficient (SAFE) rule⁴

EPA noted that emissions modelers could expect to encounter the following findings, relative to MOVES2014b:

- Lower emissions for most criteria pollutants in future years compared to MOVES2014b
- Higher emissions for greenhouse gases in near future years compared to MOVES2014b
- Results will vary based on local inputs in a given area; **however, urban areas may see NOx increases**

Regarding the potential increases in NOx emissions in urban areas, in the MOVES3 documentation,⁵ EPA notes that *“as shown in Figure 6-5, urban counties with congested roads and little hotelling activity in MOVES2014b may see higher total NOx with MOVES3 than with MOVES2014b.”* Figure 6-5 from the EPA’s documentation is shown below.

¹ USEPA, “EPA Releases MOVES3 Mobile Source Emissions Model: Questions and Answers.” Office of Transportation and Air Quality, November 2020.

² USEPA, “MOVES3: Introduction & Overview.” MOVES Review Work Group Webinar, Office of Transportation and Air Quality, December 10, 2022.

³ “Hotelling” is time spent by drivers of long-haul trucks with their trucks parked during mandatory rest periods.

⁴ Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 2021-2026 that took effect in 2020 replaced the Final Rule for Model Year 2012 – 2016 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, having the net effect of reduced fuel efficiency and higher greenhouse gas emissions rates in MOVES3 relative to MOVES2014b.

⁵ USEPA, “Overview of EPA’s Motor Vehicle Emission Simulator (MOVES3).” Assessment and Standards Division Office of Transportation and Air Quality, March 2021.

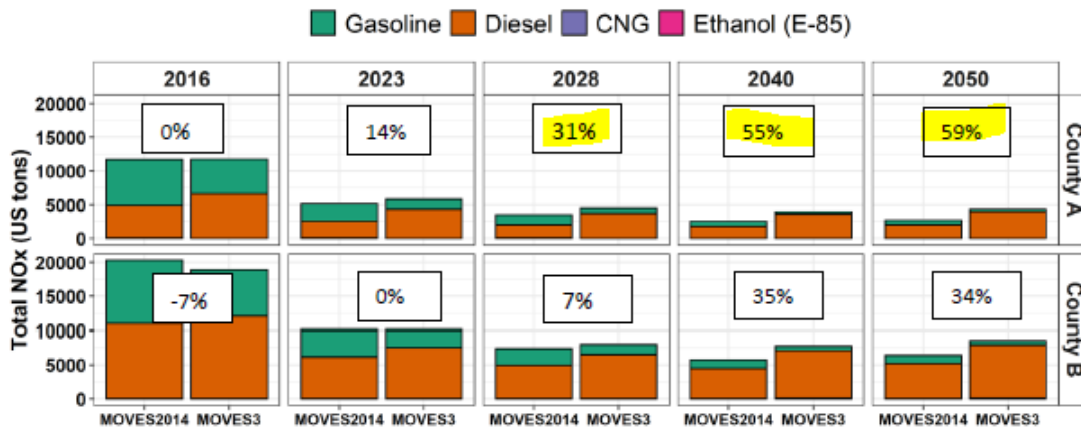


Figure 6-5—Onroad NO_x from two sample urban counties in MOVES3 as compared to MOVES2014b

Source: Overview of EPA’s MOrtor Vehicle Emission Simulator (MOVES3); March 2021

It is worth emphasizing that EPA’s own findings show that regions such as ours, with congested roads and little hotelling, could see significant NO_x increases (greater than 50% based on the analysis year, highlighted in yellow on the above figure) that are based **simply on changes in modeling methodology, without changing any of the modeling inputs.**

TPB STAFF’S PRELIMINARY TESTS – INPUTS AND RESULTS

TPB staff’s preliminary tests were designed to determine the impacts of changes to the emissions models alone – i.e., moving from MOVES2014b to MOVES3. To evaluate the impacts of the MOVES3⁶ model on the region’s ability to adhere to the current motor vehicle emissions budgets (MVEBs), TPB staff conducted several MOVES3 test runs, which used the same inputs as the corresponding MOVES2014b runs (to the extent possible). Because the Washington region is designated as being in non-attainment for the federal health standards for ozone, staff evaluated the impacts of the new MOVES model on the ground-level ozone precursors: nitrogen oxides (NO_x) and volatile organic compounds (VOC). Staff also evaluated the impacts of the new model on greenhouse gas emissions estimates, because the selected tool can have a substantial impact on the region’s ability to meet the recently adopted GHG reduction goals for the on-road transportation sector (50% below 2005 levels in 2030 and 80% below 2005 levels in 2050).

The assumptions for the two runs are summarized in Table 1, which shows that, other than the model itself, the MOVES2014b and MOVES3 tests used almost identical assumptions (differences are shown in green). It is important to note that TPB staff conducted the tests by using the MOVES2014b assumptions from the 2022 Update to Visualize 2045 analysis and kept them the same in MOVES3 (where possible). These findings are preliminary, however, and will be updated when staff receive model inputs created specifically for MOVES3.

⁶ The latest version of the MOVES3 model is called MOVES3.0.4.

Additional information on the assumptions used in setting the MVEBs is available in the Air Quality Conformity Analysis of the 2022 Update to Visualize 2045 (Full Report).⁷

Model results findings are summarized in Tables 2 through 4.

Table 1. Data Sources: MOVES Model Emissions Assumptions and Tools in Sensitivity Analysis

	MOVES2014b Baseline	MOVES3.0.4 Test
Model	MOVES2014b	MOVES3.0.4
Long-Range Transportation Plan	2022 Update	2022 Update
Cooperative Forecasts	Round 9.2	Round 9.2
Travel Demand Model	Gen2/Version 2.4	Gen2/Version 2.4
Travel Related Inputs		
Age Distribution	2020 VIN ⁸	2020 VIN
Average Speed Distribution	Gen2/Version 2.4	Gen2/Version 2.4
Road Type Distribution	Gen2/Version 2.4	Gen2/Version 2.4
Source Type Population	2020 VIN	2020 VIN
Vehicle Type VMT	Gen2/Version 2.4	Gen2/Version 2.4
Ramp Fraction	Local data	Local data
Non-Travel-Related Inputs		
Fuel	Local data (B)	Local data (B)
Alternate Vehicle & Fuel Technology (AVFT)	Local data	Default
Inspection & Maintenance (I/M) Programs	Local Data (9/16/2021)	Local Data (9/16/2021)
Meteorological Data	Local Data	Local Data

⁷ Metropolitan Washington Council of Governments. “Air Quality Conformity Analysis of the 2022 Update to Visualize 2045: Full Report.” Washington, D.C.: Metropolitan Washington Council of Governments, June 15, 2022.

⁸ Vehicle registration data, also known as vehicle identification number (VIN) data.

Table 2. Ozone NOx Emissions: MOVES3.0.4 versus MOVES2014B (in short tons/day)

Year	MOVES2014B	MOVES3.0.4	MOVES3.0.4 versus MOVES2014B
2021	66.824	67.442	1%
2023	54.016	56.382	4%
2025	42.566	46.377	9%
2030	27.536	34.666	26%
2040	19.140	29.183	52%
2045	19.131	29.434	54%

Table 3. Ozone VOC Emissions: MOVES3.0.4 versus MOVES2014B (in short tons/day)

Year	MOVES2014B	MOVES3.0.4	MOVES3.0.4 versus MOVES2014B
2021	42.341	35.046	-17%
2023	37.741	31.402	-17%
2025	34.165	28.099	-18%
2030	25.633	22.145	-14%
2040	19.559	18.017	-8%
2045	19.074	17.774	-7%

Table 4. GHG Emissions: MOVES3.0.4 versus MOVES2014B (in short tons/day)

Year	MOVES2014B	MOVES3.0.4	MOVES3.0.4 versus MOVES2014B
2021	21,977,041	23,121,707	5%
2023	21,313,142	22,555,387	6%
2025	20,558,238	21,975,342	7%
2030	19,104,155	20,830,247	9%
2040	18,509,459	20,496,504	11%
2045	18,860,675	20,871,539	11%

The main findings of the analysis are that although greenhouse gas (GHG) and VOC emissions change fairly significantly, it is the NOx emissions that change the most in MOVES3 relative to MOVES2014b (by more than 50% in certain analysis years) and pose the greatest risk to the region's ability to meet its federal obligations with respect to transportation conformity, as described further in this memorandum.

NOx Emissions

The analysis has shown that the NOx emissions change most significantly, increasing by 26% in 2030, 52% in 2040, and 54% in 2045 in MOVES3 relative to MOVES2014b (Table 2). Although each of the EPA model updates cannot be tested in isolation due to the nature of the MOVES model, this increase in NOx emissions estimates is largely driven by the changes in truck emissions in the model. This is well in line with some of the possible outcomes that the EPA documented related to the urban areas with congested roads and little hotelling activity, as noted in the earlier section of this memorandum. Furthermore, some of the TPB's peer MPOs, such as the Atlanta Regional Commission and the North Central Texas Council of Governments in Dallas, have documented similar findings, showing large increases in NOx in MOVES3 relative to MOVES2014b (by as much as 80-85% increase in NOx by 2050 in Atlanta).^{9 10}

Based on the MOVES3 testing conducted by TPB staff, due to the change in MOVES models, the region would find it challenging to remain below the current MVEBs for ozone, established in conjunction with the 2008 Ozone Maintenance Plan. In fact, Table 2 above shows that in 2030, 2040, and 2045, emissions increases resulting only from changing the model from MOVES2014b to MOVES3, and, with everything else being held equal (to the extent possible), are greater than 20%, which corresponds to the transportation buffers embedded in the "Tier 2" budgets, which were established to account for forecast uncertainties less significant than the wholesale changes in the EPA MOVES model (e.g., new vehicle mix, new demographic data).¹¹

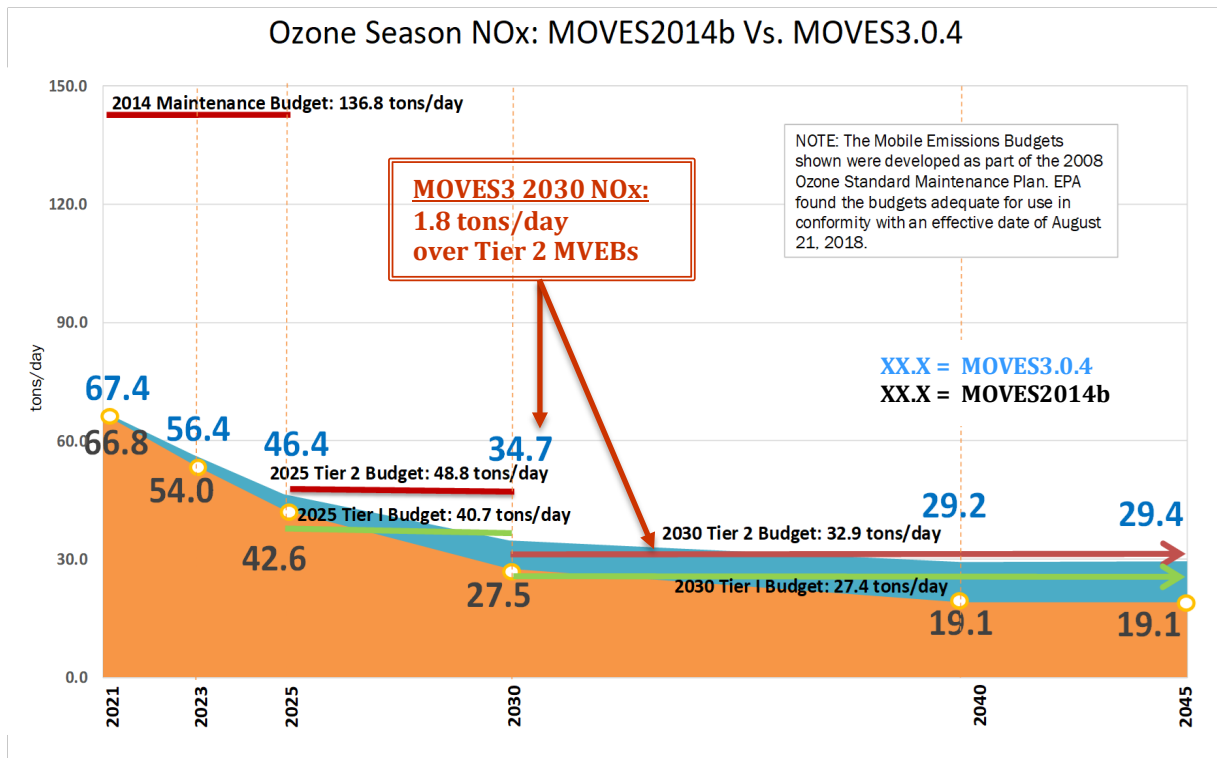
Figure 1 below shows the MOVES2014b and MOVES3 NOx emissions estimates in comparison to the "Tier 2" MVEBs. Orange shading and black numbers represent MOVES2014b. Blue shading and blue numbers represent MOVES3. The figure indicates that the changes in the modeling tools alone relative to the latest MOVES2014b AQC estimates were so significant that our region would exceed the 2030 Tier 2 budgets by 1.8 tons, or more than 5% (2030 Tier 2 budget = 32.9 tons/day, MOVES3 test estimate = 34.7). The region would also get closer to exceeding the budgets in 2025, 2040, and 2045. Using MOVES2014b, our region met the conformity requirements for every analysis year.

⁹ Grodzinsky, Gil. "Comparison of Ozone Precursor Emissions from MOVES3 & MOVES2014b." Webinar, March 18, 2021. <https://marama.org/library/>

¹⁰ Klaus, Chris, et al. "MOVES3 Experiences, Results, and Observations." MJO MOVES Workgroup, May 19, 2022.

¹¹ Metropolitan Washington Council of Governments. "Maintenance Plan for the Washington DC-MD-VA 2008 Ozone NAAQS Nonattainment Area." Washington, D.C.: Metropolitan Washington Council of Governments, December 20, 2017. <https://www.mwcog.org/documents/2017/09/18/washington-dc-md-va-2008-ozone-naaqs-marginal-nonattainment-area-redesignation-request-and-maintenance-plan-air-quality-air-quality-conformity-ozone/>

Figure 1. MOVES 2014b and MOVES3 NOx Emissions Estimates and MVEBs



NOTE: MOVES2014b emissions are from the air quality conformity analysis of the 2022 Update to Visualize 2045 and the MOVES3.0.4 emissions are from a sensitivity test using the same inputs (where possible).

VOC Emissions

Consistent with the EPA expectations, VOC emissions decrease by 17-18% in the early years and by 7-8% in the model out years (Table 3). Although these findings would make it less challenging to pass the conformity using the current MVEBs, they also indicate that there is a need to revisit the current MVEBs.

GHG Emissions

Although GHG emissions are handled outside of the air quality conformity process, climate change has become an essential part of long-range planning in the region. Based on the tests, and as shown in Table 4, GHG emissions increase by 5-11% (5% in 2021 and 11% in 2045). These increases in GHG emissions are in line with the EPA expectations in the near future, although our region is continuing to see GHG increases in MOVES3 in the out-years, which perhaps runs counter to some of the EPA expectations. It is important to note that the increases in GHG emissions associated with MOVES3 could jeopardize the region's ability to meet the 2030 and 2050 GHG reductions targets. While staff are unable to test the impacts of each individual update to the MOVES3 model, based on EPA's documentation, staff are confident that some of the GHG emission increases occur because the model reflects the Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 2021-2026 that took effect in 2020, and which rolled back the more stringent Model Year 2012-2016 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy

Standards that were reflected in MOVES2014b. The SAFE Vehicles Rule has now been superseded with a more “climate-friendly” Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards that took effect in 2022. TPB staff hope that the next update of the MOVES model reflects the current 2022 GHG emissions standards.

RECOMMENDATIONS

The Metropolitan Washington, DC, (DC-MD-VA) region has made significant improvements to air quality, as shown by the local ozone monitor measurements (decreasing from 106 parts per billion in 1999 to 70 parts per billion in 2021). The Metropolitan Washington Air Quality Committee (MWAQC) is currently developing a plan to address the 2015 Ozone National Ambient Air Quality Standards (NAAQS) requirements. Staff will be developing new MVEBs associated with this plan, and these budgets will be developed with MOVES3, which will make the future MOVES model runs for air quality conformity more compatible with the MOVES model runs used to set the budgets (i.e., MOVES3 would be used in both the budget setting and conformity).

However, as the EPA has not revoked the 2008 ozone NAAQS and the associated requirements, the region is still required to demonstrate conformity using the MVEBs set for this standard. As these MVEBs were set using MOVES2014a, without updated MVEBs based on MOVES3, the region would risk not meeting conformity requirements for any future plan update because of the requirement to use MOVES3. The model sensitivity testing has shown that, with using the same model inputs, starting with 2030, the MOVES3 NOx estimates are greater than the corresponding MOVES2014b NOx estimates by 26-54%, depending on the analysis year. This is in line with the EPA expectations for urban areas with congested conditions and with what some of the other MPOs found. The analysis has also indicated that, using MOVES3, the region would exceed the current Tier 2 MVEBs associated with the 2008 Ozone Maintenance Plan by 5% in 2030 (whereas the region met the conformity requirements for every analysis year using MOVES2014b).

Therefore, TPB staff recommend development of new MVEBs based on the MOVES3 model for the 2008 Ozone Maintenance Plan. If the region updates the MVEBs associated with the 2008 Ozone Maintenance Plan, based on this sensitivity analysis, updated NOx budgets would be expected to be higher than the current budgets, while updated VOC budgets would be expected to be lower than the current budgets. Furthermore, due to the TPB’s current schedule of having the next LRTP approved in 2024, without updated MVEBs associated with the 2008 Ozone Maintenance Plan, the region will not meet conformity requirements and therefore not be able to access additional funding for transit and highway projects specified in the Infrastructure Investment and Jobs Act.

Finally, the 2008 Ozone Maintenance Plan does allow for re-evaluation of MVEBs *“if there is a roll-back of federal emissions control programs and/or changes to USEPA’s emissions estimation model that result in significant changes in emissions inventories or to accommodate transportation planning issues when the Constrained Long-Range Plan horizon year is extended beyond 2040.”*¹²

¹² Metropolitan Washington Council of Governments. “Maintenance Plan for the Washington DC-MD-VA 2008 Ozone NAAQS Nonattainment Area.” Washington, D.C.: Metropolitan Washington Council of Governments, December 20, 2017. <https://www.mwcog.org/documents/2017/09/18/washington-dc-md-va-2008-ozone-naags-marginal-nonattainment-area-redesignation-request-and-maintenance-plan-air-quality-air-quality-conformity-ozone/>

Based on the plan approval schedule, **TPB staff recommend that the update of 2008 Ozone Maintenance Plan MVEBs be completed and provided to the EPA for review by December 2023.**

Regarding the impact of MOVES3 on GHG emissions, TPB staff recommend continuing to monitor the legislative developments and subsequent MOVES model updates to ensure that the current federal, state, and local policies are reflected as accurately as possible in modeling assumptions.