# CMAQ Emissions Calculator Toolkit

## Documentation of Emissions Data for the Diesel Idle Reduction Tool

This document supplements the User Guide for the Diesel Idle Reduction Tool in the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit). It discusses the primary data sources and how the emission datasets for this tool were derived.

The document highlights the emissions data obtained from the US Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES).[1] The MOVES Methodology section describes the specific inputs and outputs, pre-processing, and post-processing that were used to generate the national-scale[2] emission rates used within the tool. The tool also utilizes emissions data from Argonne National Laboratory, including the Alternative Fuel Lifecycle Environmental and Economic Transportation (AFLEET) Tool.[3]

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[1] US Environmental Protection Agency, Office of Transportation and Air Quality, https://www.epa.gov/moves

[2] Default-scale in MOVES3 refers to national-scale, the terminology used in previous versions of MOVES.

[3] US Department of Energy, Argonne National Laboratory, https://greet.es.anl.gov/afleet_tool

# EMISSION RATE DATA SUMMARY

Emission rates for the Diesel Idle Reduction tool were derived from two different sources: national-scale runs of MOVES3 and an Argonne National Laboratory idle reduction study.[4] MOVES is the primary data source for this tool; Argonne was used for battery APU and direct-fired heater emission rates, as these data were not available through MOVES. For battery APUs, emission rates were calculated using an alternative method based on fuel consumption described in detail below (see Battery APU Emission Rate Calculation).

Note that this tool does not account for life cycle emissions associated with the hotelling activity. For example, the tool does not consider upstream emissions from electricity production for truck stop electrification (TSE). TSE was assumed to have an emission rate of zero for all pollutants. Engine-off idling (no main or auxiliary engine use) was also assumed to have an emission rate of zero for all pollutants (see Truck Stop Electrification and Engine-off Idling for more detail).

The following table details the source of the emissions rates by type of hotelling activity:

***Table 1. Emission rate source by hotelling activity***

| Hotelling Activity | Source |
|---|---|
| Extended Idle | MOVES3 Runs |
| Diesel APU | MOVES3 Runs |
| Battery APU | Argonne idle reduction study |
| Direct-fired Heater | Calculated based on fuel consumption |
| TSE | None (assumed to be 0) |
| Engine-off | None (assumed to be 0) |

Tables 2 through 9 show emission rate data obtained for the five pollutants as well as carbon dioxide, total energy consumption, and carbon dioxide equivalents considered in the Diesel Idle Reduction Tool, organized by hotelling activity type and model year group.

***Table 2. Hotelling activity emission rates in g/hr for carbon monoxide (CO)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 54.383 | 9.956 | 2.463 | 0.437 | 0 | 0 |
| 2007-2009 | 44.798 | 9.956 | 0.510 | 0.437 | 0 | 0 |
| 2010-2012 | 39.882 | 9.956 | 1.890 | 0.437 | 0 | 0 |
| 2013-2020 | 40.103 | 9.956 | 1.325 | 0.437 | 0 | 0 |
| 2021-2023 | 39.919 | 9.956 | 1.265 | 0.437 | 0 | 0 |
| 2024-2050 | 39.908 | 9.956 | 1.359 | 0.437 | 0 | 0 |

[4] Gaines, L.L., and C.J. Brodrick. (2009). Energy Use and Emissions Comparison of Idling Reduction Options for Heavy-Duty Diesel Trucks. In Transportation Research Record: 18 TRB 88th Annual Meeting.

***Table 3. Hotelling activity emission rates in g/hr for particulate matter (PM; diameter < 2.5 µm)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 6.770 | 0.902 | 0.450 | 0.06 | 0 | 0 |
| 2007-2009 | 0.120 | 0.902 | 0.018 | 0.06 | 0 | 0 |
| 2010-2012 | 0.324 | 0.902 | 0.016 | 0.06 | 0 | 0 |
| 2013-2020 | 0.555 | 0.902 | 0.022 | 0.06 | 0 | 0 |
| 2021-2023 | 0.415 | 0.338 | 0.018 | 0.06 | 0 | 0 |
| 2024-2050 | 0.406 | 0.020 | 0.018 | 0.06 | 0 | 0 |

***Table 4. Hotelling activity emission rates in g/hr for particulate matter (diameter < 10 µm)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 7.358 | 0.980 | 0.489 | 0.06 | 0 | 0 |
| 2007-2009 | 0.131 | 0.980 | 0.019 | 0.06 | 0 | 0 |
| 2010-2012 | 0.352 | 0.980 | 0.017 | 0.06 | 0 | 0 |
| 2013-2020 | 0.603 | 0.980 | 0.024 | 0.06 | 0 | 0 |
| 2021-2023 | 0.451 | 0.368 | 0.019 | 0.06 | 0 | 0 |
| 2024-2050 | 0.441 | 0.021 | 0.02 | 0.06 | 0 | 0 |

***Table 5. Hotelling activity emission rates in g/hr for nitrogen oxides (NOx)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 145.196 | 16.635 | 9.545 | 0.2 | 0 | 0 |
| 2007-2009 | 107.668 | 16.635 | 4.313 | 0.2 | 0 | 0 |
| 2010-2012 | 48.785 | 16.635 | 2.66 | 0.2 | 0 | 0 |
| 2013-2020 | 50.196 | 16.635 | 2.17 | 0.2 | 0 | 0 |
| 2021-2023 | 49.022 | 20.790 | 2.051 | 0.2 | 0 | 0 |
| 2024-2050 | 48.952 | 16.635 | 2.118 | 0.2 | 0 | 0 |

***Table 6. Hotelling activity emission rates in g/hr for volatile organic compounds (VOC)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 29.839 | 1.521 | 0.511 | 0.174 | 0 | 0 |
| 2007-2009 | 5.775 | 1.521 | 0.072 | 0.174 | 0 | 0 |
| 2010-2012 | 2.873 | 1.521 | 0.076 | 0.174 | 0 | 0 |
| 2013-2020 | 2.845 | 1.521 | 0.058 | 0.174 | 0 | 0 |
| 2021-2023 | 2.417 | 1.521 | 0.05 | 0.174 | 0 | 0 |
| 2024-2050 | 2.391 | 0.699 | 0.05 | 0.174 | 0 | 0 |

***Table 7. Hotelling activity emission rates in g/hr for carbon dioxide (CO2)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 9070.564 | 3492.421 | 1160.542 | NA | 0 | 0 |
| 2007-2009 | 7157.564 | 3492.423 | 1160.542 | NA | 0 | 0 |
| 2010-2012 | 7204.752 | 3492.420 | 1160.542 | NA | 0 | 0 |
| 2013-2020 | 7230.637 | 3492.422 | 1160.542 | NA | 0 | 0 |
| 2021-2023 | 7209.111 | 3492.423 | 1160.542 | NA | 0 | 0 |
| 2024-2050 | 7207.816 | 3492.421 | 1160.542 | NA | 0 | 0 |

***Table 8. Hotelling activity emission rates in MMBTU/hr for total energy consumption (TEC)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 0.1167 | 0.0449 | 0.0149 | NA | 0 | 0 |
| 2007-2009 | 0.0921 | 0.0449 | 0.0149 | NA | 0 | 0 |
| 2010-2012 | 0.0927 | 0.0449 | 0.0149 | NA | 0 | 0 |
| 2013-2020 | 0.0930 | 0.0449 | 0.0149 | NA | 0 | 0 |
| 2021-2023 | 0.0928 | 0.0449 | 0.0149 | NA | 0 | 0 |
| 2024-2050 | 0.0927 | 0.0449 | 0.0149 | NA | 0 | 0 |

***Table 9. Hotelling activity emission rates in g/hr for carbon dioxide equivalents (CO2e)***

| Model Year Group | Extended Idle | Diesel APU | Battery APU | Direct-fired Heater | TSE | Engine-off |
|---|---|---|---|---|---|---|
| 2006 or earlier | 9070.562 | 3492.421 | 1160.901 | NA | 0 | 0 |
| 2007-2009 | 7282.165 | 3492.423 | 1161.978 | NA | 0 | 0 |
| 2010-2012 | 7230.077 | 3492.420 | 1161.487 | NA | 0 | 0 |
| 2013-2020 | 7245.521 | 3492.422 | 1161.190 | NA | 0 | 0 |
| 2021-2023 | 7224.175 | 3492.423 | 1161.256 | NA | 0 | 0 |
| 2024-2050 | 7222.797 | 3511.976 | 1161.332 | NA | 0 | 0 |

The hotelling emission rates data can also be viewed in the tool by un-hiding the RatesSummary tab. To view the emission rates worksheets, right-click on one of the worksheet tabs, select *Unhide*, and then select the worksheet.

Carbon dioxide in kg/day, total energy consumption (TEC) in MMBTU/day and carbon dioxide equivalents ($CO_2e$) in kg/day, are reported for diesel APU, TSE, battery APU, and engine-off idling projects. These parameters were determined from MOVES runs for Extended Idle and Hotelling Auxiliary Power (see MOVES Methodology). The reduction in $CO_2$, TEC or $CO_2e$ for diesel APUs is calculated as the difference between extended idle and diesel APU TEC for a particular model year group. Battery APU

$CO_2$, TEC, and $CO_2e$ rates were calculated using fuel consumption data, as for other pollutant emission rates for battery APUs. The reduction for TSE and engine-off idling is equal to the extended idle TEC, as these hotelling activities are assumed to have zero energy consumption or $CO_2$ emissions. $CO_2$, TEC and $CO_2e$ are not reported by the tool for projects involving direct-fired heaters, as this data is not available in the Argonne idle reduction study.

# MOVES METHODOLOGY

The Diesel Idle Reduction tool relies on extended idle exhaust and hotelling APU emissions, as well as national-scale activity rates, within MOVES. The latest version of MOVES, MOVES3, updated extended idle emission rates for THC, CO, NOx, and $PM_{2.5}$ as well as hotelling activity distributions based on the EPA's Heavy-duty Greenhouse Gas Phase 2 rulemaking. This rule included increasing the adoption of battery or electric supplemental power, which is reflected in the MOVES default hotelling activity distribution input table.[5]

PM emission rates for extended idle are lower than emissions from diesel APUs for model years 2007-2023, which may lead to increased PM emissions for some cases involving diesel APUs from these model years. To meet the new emission standard of 0.02 g/hr, the HD GHG2 rule will require use of diesel particulate filters beginning in 2024.

Running exhaust emission rates were also obtained to calculate emission rates associated with battery APU use (see Argonne National Laboratory Data Sources and the User Guide for further detail). Evaporative and start emissions were not included in this analysis.

MOVES3 (version 3.0.3 from June 2022) was used to obtain national-scale emission rates for six different model year groups: 2006 or earlier, 2007-2009, 2010-2012, 2013-2020, 2021-2023, and 2024-2050.[6] All MOVES runs for this tool considered a single vehicle type (combination long-haul truck) and fuel (diesel).

## National-Scale Runs

Three different sets of national-scale runs were conducted to obtain emission rates:

Extended Idle – These runs were used to obtain emission rates for engine-on idling, which accounts for 100% of the hotelling activity before the project and user-defined hotelling activity after project implementation. In MOVES, all extended idle exhaust and crankcase extended idle exhaust (processID 90 and 17) is assumed to occur off-network during extended idling hours (activityTypeID 3). See Table 9 for parameters used in Extended Idle MOVES runs.

Hotelling Auxiliary Power – These runs were used to obtain emission rates for diesel APUs, one of the idle reduction projects available for modeling with this tool. All auxiliary power exhaust (processID 91) in MOVES is assumed to occur off-network during hotelling diesel auxiliary hours (activityTypeID 13). See Table 10 for parameters used in Hotel Auxiliary Power MOVES runs.

Running – These runs were used to obtain emission rates and total energy consumption for long-haul trucks during normal engine operation. Running emission rates were calculated by dividing the running exhaust and running crankcase exhaust (processID 1 and 15) by the source hours operated

[5] EPA, Population and Activity of Onroad Vehicles in MOVES3 (EPA-420-R-21-012, April 2021)
[6] EPA, Latest Version of MOtor Vehicle Emission Simulator (MOVES) | US EPA

(activityTypeID 4). These rates were used to derive emission rates for battery APUs, as described in further detail below and in the User Guide. See Table 11 for parameters used in Running MOVES runs.

*Table 10. Extended Idle Parameters*

| Categories | Variable | Input |
|---|---|---|
| **Description** | ----- | <blank> |
| **Scale** | Model | Onroad |
| | Domain/Scale | National |
| | Calculation Type | Inventory |
| **Time Spans** | Time Aggregation Level | Year |
| | Years | [2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040] |
| | Months | All Selected |
| | Days | All Selected |
| | Hours | All Selected |
| **Geographic Bounds** | ----- | Nation |
| **Vehicles/Equipment** | On-Road Vehicle Equipment | Diesel Combination Long-haul Trucks |
| **Road Type** | Road Type | Off-Network |
| **Pollutants and Processes (selected)** | Total Gaseous Hydrocarbons | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Non-methane Hydrocarbons | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Non-methane Organic Gases | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Volatile Organic Compounds | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Methane | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Carbon Monoxide | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Oxides of Nitrogen | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Primary Exhaust $PM_{2.5}$ – Total | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Primary Exhaust $PM_{2.5}$ - Species | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Primary Exhaust $PM_{10}$ – Total | Extended Idle Exhaust, Extended Idle Crankcase Exhaust |
| | Total Energy Consumption | Extended Idle Exhaust |
| | Atmospheric $CO_2$ | Extended Idle Exhaust |
| | $CO_2$ Equivalent | Extended Idle Exhaust |
| **Manage Input Data Series** | ----- | <blank> |
| **Strategies** | Rate of Progress | <blank> |

| Categories | Variable | Input |
|---|---|---|
| **General Output** | Units | Mass: kilograms, Energy: million BTU, Distance: miles |
| | Activity | Hotelling Hours |
| **Output Emissions Detail** | Always | Year, Nation |
| | On Road/Off Road | <no selections> |
| | For All Vehicle/Equipment Combinations | Model Year |
| **Advanced Performance Features** | ----- | <blank> |

*Table 11. Hotelling Auxiliary Power Parameters*

| Categories | Variable | Input |
|---|---|---|
| **Description** | ----- | <blank> |
| **Scale** | Model | Onroad |
| | Domain/Scale | National |
| | Calculation Type | Inventory |
| **Time Spans** | Time Aggregation Level | Year |
| | Years | [2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040] |
| | Months | All Selected |
| | Days | All Selected |
| | Hours | All Selected |
| **Geographic Bounds** | ----- | Nation |
| **Vehicles/Equipment** | On-Road Vehicle Equipment | Diesel Combination Long-haul Trucks |
| **Road Type** | Road Type | Off-Network |
| **Pollutants and Processes (selected)** | Total Gaseous Hydrocarbons | Auxiliary Power Exhaust |
| | Non-methane Hydrocarbons | Auxiliary Power Exhaust |
| | Non-methane Organic Gases | Auxiliary Power Exhaust |
| | Volatile Organic Compounds | Auxiliary Power Exhaust |
| | Methane | Auxiliary Power Exhaust |
| | Carbon Monoxide | Auxiliary Power Exhaust |
| | Oxides of Nitrogen | Auxiliary Power Exhaust |
| | Primary Exhaust $PM_{2.5}$ – Total | Auxiliary Power Exhaust |
| | Primary Exhaust $PM_{2.5}$ - Species | Auxiliary Power Exhaust |
| | Primary Exhaust $PM_{10}$ – Total | Auxiliary Power Exhaust |
| | Total Energy Consumption | Auxiliary Power Exhaust |
| | Atmospheric $CO_2$ | Auxiliary Power Exhaust |
| | $CO_2$ Equivalent | Auxiliary Power Exhaust |
| **Manage Input Data Series** | ----- | <blank> |
| **Strategies** | Rate of Progress | <blank> |

| Categories | Variable | Input |
|---|---|---|
| **General Output** | Units | Mass: kilograms, Energy: million BTU, Distance: miles |
| | Activity | Hotelling Hours |
| **Output Emissions Detail** | Always | Year, Nation |
| | On Road/Off Road | <no selections> |
| | For All Vehicle/Equipment Combinations | Model Year |
| **Advanced Performance Features** | ----- | <blank> |

*Table 12. Running Parameters*

| Categries | Variable | Input |
|---|---|---|
| **Description** | ----- | <blank> |
| **Scale** | Model | Onroad |
| | Domain/Scale | National |
| | Calculation Type | Inventory |
| **Time Spans** | Time Aggregation Level | Year |
| | Years | [2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040] |
| | Months | All Selected |
| | Days | All Selected |
| | Hours | All Selected |
| **Geographic Bounds** | ----- | Nation |
| **Vehicles/Equipment** | On-Road Vehicle Equipment | Diesel Combination Long-haul Trucks |
| **Road Type** | Road Type | All Road Types |
| **Pollutants and Processes (selected)** | Total Gaseous Hydrocarbons | Running Exhaust, Crankcase Running Exhaust |
| | Non-methane Hydrocarbons | Running Exhaust, Crankcase Running Exhaust |
| | Non-methane Organic Gases | Running Exhaust, Crankcase Running Exhaust |
| | Volatile Organic Compounds | Running Exhaust, Crankcase Running Exhaust |
| | Methane | Running Exhaust, Crankcase Running Exhaust |
| | Carbon Monoxide | Running Exhaust, Crankcase Running Exhaust |
| | Oxides of Nitrogen | Running Exhaust, Crankcase Running Exhaust |
| | Primary Exhaust $PM_{2.5}$ – Total | Running Exhaust, Crankcase Running Exhaust |

| Categries | Variable | Input |
|---|---|---|
| | Primary Exhaust $PM_{2.5}$ - Species | Running Exhaust, Crankcase Running Exhaust |
| | Total Energy Consumption | Running Exhaust |
| | Atmospheric $CO_2$ | Running Exhaust |
| | $CO_2$ Equivalent | Running Exhaust |
| **Manage Input Data Series** | ----- | <blank> |
| **Strategies** | Rate of Progress | <blank> |
| **General Output** | Units | Mass: kilograms, Energy: million BTU, Distance: miles |
| | Activity | Source Hours Operating Population |
| **Output Emissions Detail** | Always | Year, Nation |
| | On Road/Off Road | Road Type |
| | For All Vehicle/Equipment Combinations | Model Year |
| **Advanced Performance Features** | ----- | <blank> |

## Default Activity by Model Year Group

The last set of MOVES runs (Table 11) was also used to determine the national default activity distribution by model year (MY) group for source hours operated (activityTypeID 4) and population (activityTypeID 6). National default activity fractions were determined by summing the MOVES activity in a model year group (2006 and earlier, 2007-2009, 2010-2012, 2013-2020, 2021-2023, 2024-2050) and dividing by the MOVES total activity across all model years for a particular project evaluation year. The activity in a model year group was calculated by multiplying the default fraction (e.g., fraction of 2013-2020 vehicle activity in project evaluation year 2022) by the annual activity input by the user.

For a specific project evaluation year (yearID), the activity in a model year group is calculated as:

$$Activity\ in\ MY\ Group = \left(\frac{MOVES\ Activity\ in\ MY\ Group}{MOVES\ Total\ \ Activity\ Across\ All\ MYs}\right) \times Annual\ Activity \quad (1)$$

$$Activity\ in\ MY\ Group = National\ Default\ Fraction \times Annual\ Activity \quad (2)$$

For example, for a project evaluation year of 2022, model year group 2013-2020, and annual activity input by the user of 1,000 (operating hours or vehicles): [7]

Operating hours in model year group (2013-2020) = 2,262,610,813
Total operating hours across all model years (1992-2022)[8] = 3,631,969,900
National default fraction (operating hours) = 0.623
Activity in model year group = 0.623 × 1,000 = 623 operating hours

Population in model year group (2013-2020) = 857,928
Total population across all model years (1992-2022) = 1,814,526
National default fraction (population) = 0.473
Activity in model year group = 0.473 × 1,000 = 473 vehicles

See Figures 1 and 2 in the appendix for the distribution of national default fractions by project evaluation year for each model year group.

[7] See Example 1 in the User Guide for how to use the Activity Calculator in the tool to generate an activity distribution based on national MOVES defaults.
[8] Activity was summed for the project evaluation year and the past 30 years (e.g., for 2022, years 1992-2022).

## Pre-MOVES Run Data Processing

MOVES3 updated the default hotelling activity fractions included in the default input database. In MOVES2014a, the default hotelling activity fractions are set to 100% extended idle for years 2009 and earlier, and 70% extended idle / 30% diesel APU for years 2010 and later as shown in Table 12. In MOVES3, the default hoteling activity fractions were updated based on the HD GHG Phase 2 rule as shown in Table 13, which includes 20 percent of engine off to represent 2 hours of off-duty time. To obtain extended idle and diesel APU emission rates, pre-processing was required to re-allocate hotelling activity to individual activity types.

The hotellingActivityDistribution table in the MOVES input database (Table 13) was modified depending on the operating mode, where operating mode refers to the type of emission-producing activity (e.g., extended idling or hotelling diesel auxiliary). Table 14 describes operating modes associated with various hotelling activities.

***Table 13. MOVES2014a Hotelling Activity Distribution Input Table***

| beginModelYearID | endModelYearID | opModeID | opModeFraction |
|---|---|---|---|
| 1960 | 2009 | 200 | 1 |
| 2010 | 2050 | 200 | 0.7 |
| 1960 | 2009 | 201 | 0 |
| 2010 | 2050 | 201 | 0.3 |
| 1960 | 2009 | 203 | 0 |
| 2010 | 2050 | 203 | 0 |
| 1960 | 2009 | 204 | 0 |
| 2010 | 2050 | 204 | 0 |

***Table 14. MOVES3 Hotelling Activity Distribution Input Table***

| beginModelYearID | endModelYearID | opModeID | opModeFraction |
|---|---|---|---|
| 1960 | 2009 | 200 | 0.8 |
| 2010 | 2020 | 200 | 0.73 |
| 2021 | 2023 | 200 | 0.48 |
| 2024 | 2026 | 200 | 0.4 |
| 2027 | 2060 | 200 | 0.36 |
| 1960 | 2009 | 201 | 0 |
| 2010 | 2020 | 201 | 0.07 |
| 2021 | 2023 | 201 | 0.24 |
| 2024 | 2026 | 201 | 0.32 |
| 2027 | 2060 | 201 | 0.32 |
| 1960 | 2009 | 203 | 0 |
| 2010 | 2020 | 203 | 0 |
| 2021 | 2023 | 203 | 0.08 |
| 2024 | 2026 | 203 | 0.08 |
| 2027 | 2060 | 203 | 0.12 |
| 1960 | 2009 | 204 | 0.2 |

| | | | |
|---|---|---|---|
| 2010 | 2020 | 204 | 0.2 |
| 2021 | 2023 | 204 | 0.2 |
| 2024 | 2026 | 204 | 0.2 |
| 2027 | 2060 | 204 | 0.2 |

*Table 15. MOVES Operating Mode ID Descriptions*

| opModeID | opModeName |
|---|---|
| 200 | Extended Idling |
| 201 | Hotelling Diesel Aux |
| 203 | Hotelling Battery AC |
| 204 | Hotelling APU Off |

For extended idle MOVES runs, the opModeFraction for opModeID 200 was set to one and all other opModeFraction values were set to zero. For hotelling auxiliary power MOVES runs, the opModeFraction for opModeID 201 was set to one. All other opModeFraction values were set to zero.

Once these modifications were made to Table 13, the following steps were taken in the MOVES graphical user interface to override default hotelling activity:

Create Input Database → Select appropriate input database

Create Input Database → Enter/Edit Data → Hotelling tab → HotellingActivityDistribution Data Source → Browse → Upload Data File (.csv or .xlsx format).

## Post-MOVES Run Data Processing

Results from the national-scale MOVES runs were utilized to obtain different categories of data for use in this Diesel Idle Reduction tool. The following section describes MOVES activity and emissions inventory data used in the tool:

1. **Activity rates –** To obtain national-scale activity rates, the number of extended idle hours, hotelling diesel auxiliary hours, and source hours operated were extracted from the results for all vehicles.
2. **Hourly emissions –** Emission rates were generated on a per-hour basis. This involved joining emission inventories from the movesoutput table and activity from the movesactivityoutput table.
    - Extended idle emission rates: extended idle exhaust and crankcase extended idle exhaust emissions (processID 90 and 17) were divided by extended idle hours (activityTypeID 3).
    - Diesel APU emission rates: auxiliary power exhaust emissions (process ID 91) were divided by hotelling diesel auxiliary hours (activityTypeID 13)
    - Running emission rates: running exhaust and crankcase running exhaust (processID 1 and 15) were divided by source hours operating (activityTypeID 4).

# ARGONNE NATIONAL LABORATORY DATA SOURCES

Emission rates for some idle reduction technologies were not available through MOVES. Argonne National Laboratory's AFLEET 2020 and an idle reduction research study were used to obtain emission and fuel use rates for battery APUs and direct-fired heaters (see User Guide for additional detail).

## Battery APU Emission Rate Calculation

Battery APU emission rates for NOx and $PM_{10}$ were reported in Gaines and Brodrick (2009).[9] However, emission rates for CO and VOC were not available through the same study or other EPA and Argonne resources. After consultation with Argonne, an alternative method was developed to calculate battery APU emission rates for all pollutants and model year groups.

Battery APU emission rates were determined through a fuel consumption surrogate method. A battery APU fuel use rate obtained from AFLEET 2020 was used in conjunction with the long-haul truck running emission rates (as opposed to the idling rates) and total energy consumption from MOVES to generate an emission rate for battery APUs.

The total energy consumption from MOVES is given in units of MMBTU/hr. This value was converted to fuel use in gal/hr using the average energy content of diesel of 0.137 MMBTU/gal.[10]

***Table 16. Running exhaust emission rates and total energy consumption obtained from MOVES runs***

| Model Year Group | CO (g/hr) | PM2.5 (g/hr) | PM10 (g/hr) | NOx (g/hr) | VOC (g/hr) | $CO_2$ (g/hr) | TEC (MMBTU/hr) | $CO_2e$ (g/hr) |
|---|---|---|---|---|---|---|---|---|
| 2006 or earlier | 169.15 | 30.87 | 33.56 | 655.49 | 35.07 | 79700.51 | 1.03 | 79725.18 |
| 2007-2009 | 34.96 | 1.22 | 1.32 | 295.39 | 4.92 | 79490.30 | 1.02 | 79588.64 |
| 2010-2012 | 134.60 | 1.14 | 1.24 | 189.43 | 5.44 | 82639.47 | 1.06 | 82706.80 |
| 2013-2020 | 81.58 | 1.36 | 1.48 | 133.59 | 3.59 | 71448.68 | 0.92 | 71488.56 |
| 2021-2023 | 66.85 | 0.95 | 1.03 | 108.38 | 2.63 | 61323.84 | 0.79 | 61361.58 |
| 2024-2050 | 62.79 | 0.84 | 0.92 | 97.88 | 2.32 | 53618.09 | 0.69 | 53654.59 |

In order to estimate battery APU emission rates (**Error! Reference source not found.**), the ratio of the long-haul combination truck running emission rate to the running fuel flow rate may be considered proportional to the ratio of the battery APU emission rate to the battery APU fuel flow rate.[11]

$$\frac{Running\ Emission\ Rate\ (\frac{g}{hr})}{Running\ Fuel\ Use\ Rate\ (\frac{gal}{hr})} = \frac{Battery\ APU\ Emission\ Rate\ (\frac{g}{hr})}{Battery\ APU\ Fuel\ Use\ Rate\ (\frac{gal}{hr})} \qquad (3)$$

[9] Gaines, L.L., and C.J. Brodrick. (2009). Energy Use and Emissions Comparison of Idling Reduction Options for Heavy-Duty Diesel Trucks. In Transportation Research Record: 18 TRB 88th Annual Meeting.

[10] U.S. Energy Information Administration: https://www.eia.gov/energyexplained/index.php?page=about_energy_units

[11] The ancillary energy load required to charge the battery APU was assumed negligible compared with the base running energy use.

Solving for the battery APU emission rate:

$$Battery\ APU\ Emission\ Rate\ \left(\frac{g}{hr}\right) = \frac{Running\ Emission\ Rate_{i,m,y}(\frac{g}{hr})}{Running\ Fuel\ Use\ Rate_{i,m,y}(\frac{gal}{hr})} \times Battery\ APU\ Fuel\ Use\ Rate\ \left(\frac{gal}{hr}\right) \quad (4)$$

The running emission rate and running fuel use rate are then calculated for pollutant *i*, model year group *m*, and evaluation year *y*:

$$Running\ Emission\ Rate_{i,m,y}\left(\frac{g}{hr}\right) = \frac{Running\ Emissions\ Inventory_{i,m,y}(g)}{Source\ Hours\ Operated_{i,m,y}(hr)} \quad (5)$$

$$Running\ Fuel\ Use\ Rate_{i,m,y}\left(\frac{gal}{hr}\right) = \frac{Running\ Energy\ Rate\ \left(\frac{MMBTU}{hr}\right)}{Diesel\ Energy\ Content\ \left(\frac{MMBTU}{gal}\right)} \quad (6)$$

$$= \frac{\frac{Running\ Energy\ Inventory_{i,m,y}(MMBTU)}{Source\ Hours\ Operated_{i,m,y}(hr)}}{Diesel\ Energy\ Content\ \left(\frac{MMBTU}{gal}\right)}$$

The running emission rates and running energy rates (Table 11) were derived from MOVES output and the battery APU fuel use rate (0.109 gal/hr) was obtained from AFLEET 2020. The fuel use rate represents the additional diesel fuel required to recharge battery APUs and is based on average vehicle load, engine efficiency, and alternator efficiency during normal engine operation (running fuel consumption).

***Table 17. Battery APU Emission Rates Determined from Fuel Consumption***

| Model Year Group | CO (g/hr) | $PM_{2.5}$ (g/hr) | $PM_{10}$ (g/hr) | NOx (g/hr) | VOC (g/hr) | $CO_2$ (g/hr) | TEC (MMBTU/hr) | $CO_2e$ (g/hr) |
|---|---|---|---|---|---|---|---|---|
| 2006 or earlier | 2.463 | 0.450 | 0.489 | 9.545 | 0.511 | 1160.542 | 0.015 | 1160.901 |
| 2007-2009 | 0.510 | 0.018 | 0.019 | 4.313 | 0.072 | 1160.542 | 0.015 | 1161.978 |
| 2010-2012 | 1.890 | 0.016 | 0.017 | 2.660 | 0.076 | 1160.542 | 0.015 | 1161.487 |
| 2013-2020 | 1.325 | 0.022 | 0.024 | 2.170 | 0.058 | 1160.542 | 0.015 | 1161.190 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2021-2023 | 1.265 | 0.018 | 0.019 | 2.051 | 0.050 | 1160.542 | 0.015 | 1161.256 |
| 2024-2050 | 1.359 | 0.018 | 0.020 | 2.118 | 0.050 | 1160.542 | 0.015 | 1161.332 |

### Direct Fired Heater Emissions Rates

Direct-fired heater emission rates for NOx, $PM_{10}$, CO, and VOC were obtained directly from Gaines and Brodrick (2009). $PM_{2.5}$ emission rates were assumed to be equivalent to $PM_{10}$ rates for purposes of this tool. This provides a conservative estimate of PM2.5 emissions.

## TRUCK STOP ELECTRIFICATION

The Diesel Idle Reduction Tool includes TSE as an idle reduction technology option. Although there are emissions associated with production of electricity upstream of the TSE infrastructure, these emissions are not considered as part of this tool. TSE emissions are assumed to equal zero; replacement of extended idle activity with TSE activity will always result in an emissions reduction.

## ENGINE-OFF IDLING

The tool includes engine-off idling as an idle-reduction method (see Example 1 and the Appendix in the User Guide for additional information). As with TSE, there are zero emissions associated with engine-off idling and replacement of extended idling with engine-off idling will always result in a reduction in emissions.

## USER-SUPPLIED EMISSION RATES

Some users may be interested in incorporating local data into the tool's original emission rates, based on national-scale MOVES runs. For those unfamiliar with developing local MOVES runs, please refer to EPA's mobile-source emissions modeling guidance and documentation for highway vehicles.[12] This section provides basic instructions on how to import local emission rates into the Diesel Idle Reduction Tool.

Users may take the following steps to replace emission rates in the Diesel Idle Reduction Tool:

1. Using the national idle reduction run parameters listed in MOVES Methodology (Table 6 and
2. ), develop local emission rates. The CMAQ Emissions Calculator Toolkit does not prescribe which MOVES inputs are derived from local data. Users must specify the same output parameters and details as the national-scale run. Complete any local MOVES runs for the selected calendar years and any other parameters listed above.

3. Reformat the MOVES output so that it can be used in the tool, as described below:
    - Unhide the 'RatesLookup' tab in Excel and ensure that the new user-supplied, local emissions output has the same fields: pollutantID, MYGroupID, TechID, EmissionRate. Codes for these fields are given below.

[12] EPA, https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs

PollutantID Codes – designates criteria pollutant

| | |
|---|---|
| 2 | CO |
| 3 | NOx |
| 87 | VOCs |
| 90 | $CO_2$ |
| 91 | TEC |
| 98 | $CO_2e$ |
| 110 | $PM_{2.5}$ |
| 100 | $PM_{10}$ |

MYGroupID Codes – designates model year group

| | |
|---|---|
| 1 | 2006 or earlier |
| 2 | 2007-2009 |
| 3 | 2010-2012 |
| 4 | 2013-2020 |
| 5 | 2021-2023 |
| 6 | 2024-2050 |

TechID Code – designates idle reduction method

| | |
|---|---|
| 1 | Extended Idle |
| 2 | Diesel APU |
| 3 | Battery APU |
| 4 | Direct-fired Heater |
| 5 | TSE |
| 6 | Engine-off |

- To post-process the new emission rates output from MOVES, users should join the movesoutput and movesactivityoutput tables using yearID and modelYearID.
- Emission rates are calculated by dividing the emissions inventory by activity for each combination of yearID and pollutantID. Refer to Post-MOVES Run Data Processing for further detail.

The local MOVES data should now be structured and labelled exactly as the national default data initially used in the tool. Export the local emission rates in .csv or .xlsx file format.

4. Delete any data in the 'RatesSummary' tab and then copy and paste the local emission rates into the existing worksheet. Save the Diesel Idle Reduction Tool under a different name and verify that the calculator yields new, expected results with the local data.

To update $CO_2e$ or TEC rates, follow a similar process:

1. Unhide the 'CO2e Rates' and 'TEC Rates' tabs in Excel.

2. Obtain emissions data for $CO_2e$ (pollutantID 98) and TEC (pollutantID 91) from any local MOVES runs and calculate the emission rates (ER).

    - Ensure the output has the same fields: yearID, pollutantID, modelYearID, emissionsQuant, activity, ER-per hour
    - Emission rates are calculated by dividing the emissions inventory by activity for each combination of yearID, modelYearID, and pollutantID. Refer to Post-MOVES Run Data Processing for further detail.

3. Delete any data in columns A through F and copy and paste the local MOVES data and emission rates into the existing worksheet. Excel will automatically update calculations for $CO_2e$ and TEC rates by model year group. Save the Diesel Idle Reduction Tool under a different name and verify that the calculator yields new, expected results with the local data.

Note $CO_2e$ and TEC can only be derived from MOVES for extended idle and diesel APUs. Diesel APU rates are constant across project evaluation year and model year groups.

# Appendix – National Default Fractions

The distribution of national default activity fractions by project evaluation year for each model year group is shown in Figure 1 and Figure 2 for annual truck population and annual operating hours, respectively. Each color represents a project evaluation year from 2018 to 2040.

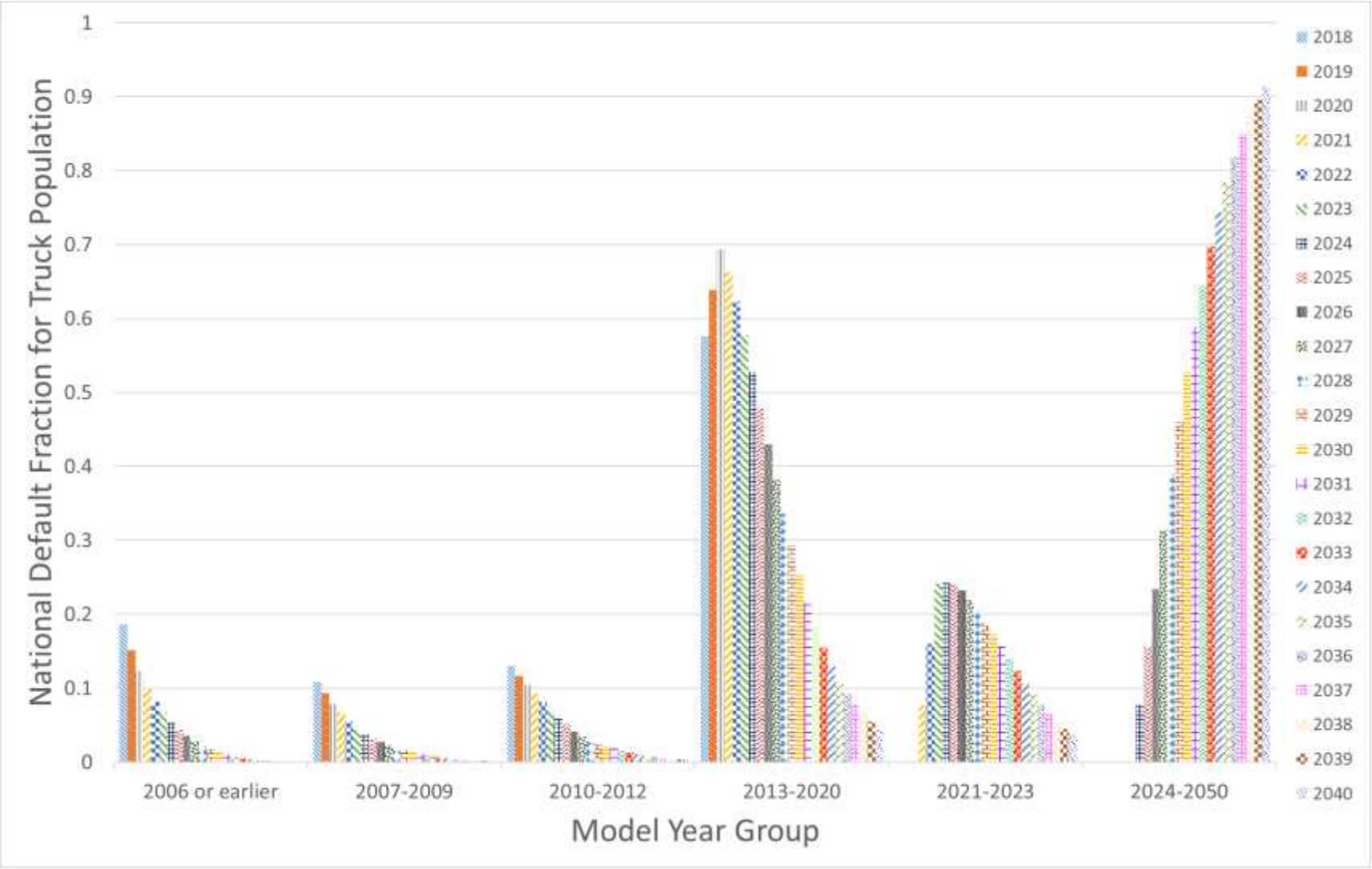


***Figure 1. National default activity fractions (annual truck population) by project evaluation year for each model year group in the Diesel Idle Reduction tool.***

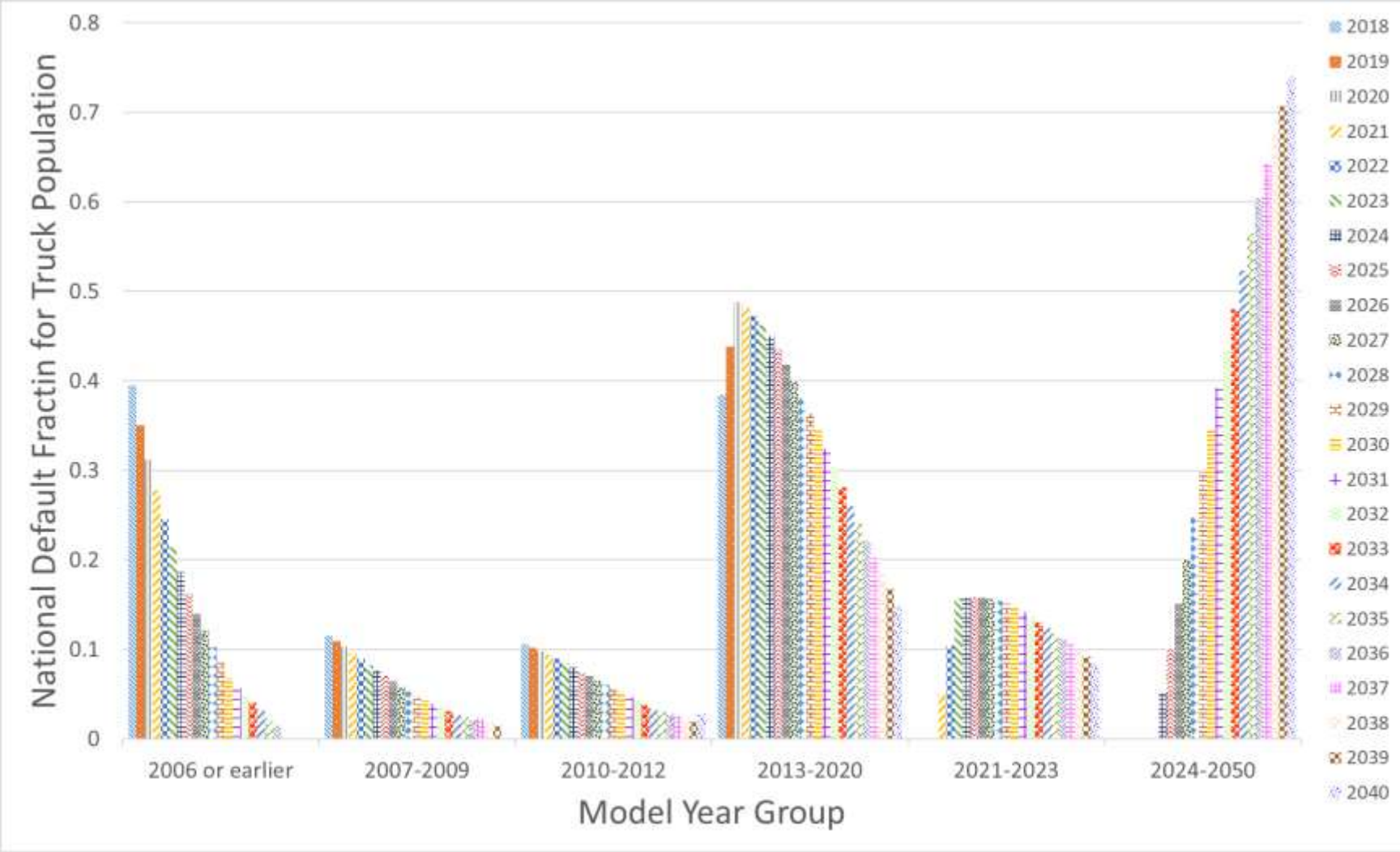


***Figure 2. National default activity fractions (annual operating hours) by project evaluation year for each model year group in the Diesel Idle Reduction tool.***