Updates to the Greenhouse Gas and Energy Consumption Rates in MOVES2010a

United States
Environmental Protection
Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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Contents

1 Updates to Energy Rates and Sourcebin Distribution for MOVES2010a

1.1 Introduction

MOVES is the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator. It helps to answer "what if" questions, such as "How would particulate matter emissions decrease in my state on a typical weekday if truck travel was reduced during rush hour?" or "How does the total hydrocarbon emission rate change if my fleet switches to gasoline from diesel fuel?" The purpose of the tool is to provide an accurate estimate of emissions from mobile sources under a wide range of user-defined conditions. It is a state-of-the-art upgrade to EPA's modeling tools for estimating emissions from highway vehicles, based on analysis of millions of actual emission test results and considerable advances in the Agency's understanding of vehicle emissions.

MOVES2010 was released in December of 2009. MOVES2010a was released in the summer of 2010 and updated MOVES2010. MOVES2010a incorporates new car and light truck greenhouse gas emissions standards affecting model years 2012 and later (published May 7, 2010) and updates to the Corporate Average Fuel Economy (CAFE) standards affecting model years 2008 through 2011.[1] MOVES2010a includes reductions in greenhouse gas emission rates associated with those standards in future calendar years, and small reductions in refueling and sulfur-related emissions associated with the reductions in vehicle fuel consumption. This document details some of the updates for the MOVES2010a release. Specifically, the updates described in this document include:

- Updates to the MOVES database to reflect new data and projections for 2008 and newer light duty energy rates
    - Model year 2008-2010 vehicle data
    - Model year 2011 Fuel Economy (FE) final rule projections
    - Model year 2012-2016 FE/GHG final rule projections
    - Corrections to model year 2000+ light duty diesel energy start rates
- Modifications to the organization of energy rates in MOVES database (DB)
    - Improved consistency between energy rates and remainder of MOVES
    - Redefined energy rate structure
    - Removed unused engine technologies from the MOVES DB
    - Removed unused emission rates from MOVES DB

This report also documents the methane and nitrous oxide rates, and includes discussion of the changes made in MOVES2010a in the way that methane emissions are determined for all vehicle types and model years.

This report assumes that the user is familiar with the MOVES model and its database design. A detailed knowledge of the emission rate structure may prove helpful to the reader.

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[1] MOVES2010a, which only contains regulations that were final as of its release, does not reflect the impacts of Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (finalized in 2011) or the Proposed Rulemaking to Establish 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and CAFE Standards (published in 2011).

Additional detail on MOVES is available on the MOVES technical background website (http://www.epa.gov/otaq/models/moves/movesback.htm).

1.2 Background: Energy Rates in the MOVES model

The energy rates in MOVES2010 were originally developed for MOVES2004, and are documented in "MOVES2004 Energy and Emission Inputs Draft Report" (EPA420-P-05-003). As documented in that report, EPA created the MOVES 2004 energy rates by analyzing second by second (1 Hz) resolution data from 16 EPA test programs covering approximately 500 vehicles and 26 non-EPA test programs covering approximately 10,760 vehicles. "Holes" in the data were filled using either the Physical Emission Rate Estimator (PERE) [2] or interpolation.

A partial timeline of the energy rates in MOVES is presented below.

- **MOVES2004**
  - Released with a full suite of energy rates to allow estimation of fuel consumption and GHG emissions.
  - Energy rates developed for fine detail of vehicle attribute and advanced technology, anticipating need for policy modeling (ex. "*How does reducing vehicle weight affect energy consumption?*")
  - Documentation: MOVES2004 Energy and Emission Rate Inputs (Report: EPA420-P-05-003, February 2005)
- **MOVES2010**
  - Relatively minor updates from MOVES2004
  - Heavy Duty energy rates updated based on new scaled tractive power (STP) methodology
  - LD rates updated to include 2008-2011 model year 2011 Corporate Average Fuel Economy (CAFE) Standards for light trucks
- **MOVES2010a**
  - Light Duty energy rates updated substantively to account for CAFE model year 2011, LD GHG model year 2012-2016 standards
  - All energy rates updated structurally to greatly simplify MOVES' energy approach with focus on inventory development , rather than policy modeling

As seen above, between MOVES 2004 and MOVES2010a, MOVES shifted being from a technology modeling tool to primarily serving as an inventory model. This shift was partially driven by the emergence of the EPA OMEGA (Optimization Model for reducing Emissions of Greenhouse gases from Automobiles) model.[3] OMEGA, which EPA used in recent mobile source greenhouse gas (GHG) rulemakings, [4] estimates the technology cost and emission impacts of vehicle GHG standards. Many light duty energy policy questions no longer are estimated by

[2] Report: Fuel Consumption Modeling of Conventional and Advanced Technology Vehicles in the Physical Emission Rate Estimator (PERE) EPA420-P-05-001, February 2005
[3] OMEGA web address: http://www.epa.gov/otaq/climate/models.htm
OMEGA Version 1.3 documentation: EPA-420-B-10-042
[4] Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule: EPA-HQ-OAR-2009-0472-11424

EPA with the MOVES model, but rather with the more narrowly focused OMEGA model. At the same time, the MOVES model has become the official EPA model for estimating mobile source emissions in State Implementation Plans and conformity modeling.[5]

Due to this change in scope, EPA reevaluated the structure of the energy rates for MOVES2010a. In MOVES, emission rates[6] are defined by vehicle emission category (sourcebin) discriminators which describe combinations of vehicle attributes. MOVES allows different emission rates to be defined by different sourcebin discriminators; a given combination of pollutant and process can require any combination of the discriminators listed in Table 1-1.

Table 1-1 – Sourcebin Discriminators

Sourcebin Discriminators
Fuel type
Engine Technology
Regulatory Class
Model Year Group
Engine Size
Weight Class

Ultimately, these discriminators are strung together in a rigidly defined format and are used as unique database keys in the “emissionrate” or “emissionratebyage” tables in MOVES. Not all source type/pollutant/process combinations require data for all sourcebinid components, and unused components of the sourcebinid can be left as zeros.[7] Previous versions of MOVES, including MOVES2010, require that energy rates discriminate by all sourcebinid components other than regulatory class (Table 1-2).

[5] Policy Guidance on the Use of MOVES2010 and Subsequent Minor Revisions for State Implementation Plan Development, Transportation Conformity, and Other Purposes, April 2012, http://www.epa.gov/otaq/models/moves/documents/420b12010.pdf

[6] The MOVES design treats energy consumption as an emission rate. Therefore, in this document, the term emissions is interchangeably used to refer to energy.

[7] The table “sourcetypepolprocess” in the MOVES DB controls which components of the sourcebinid are required for each sourcetype, pollutant, and process combination.

Table 1-2 - MOVES 2004 Energy Sourcebin Discriminators

Fuel Type	Engine Technology	Model Year Group	Loaded Weight	Engine Size
Gas Diesel CNG LPG Ethanol (E85) Methanol (E85) Gas H_2 Liquid H_2 Electric	Conventional IC (CIC) Advanced IC (AIC) Moderate Hybrid - CIC Full Hybrid - CIC Moderate Hybrid - AIC Full Hybrid - AIC Fuel Cell Hybrid - Fuel Cell (See Table 4-14 for combinations of fuel type and engine technology used in MOVES2004)	1980 and earlier 1981-85 1986-90 1991-2000 2001-2010 2011-2020 2021 and later	Null <= 2000 lbs 2001-2500 2501-3000 3001-3500 3501-4000 4001-4500 4501-5000 5001-6000 6001-7000 7001-8000 8001-9000 9001-10,000 10,001-14,000 14,001-16,000 16,001-19,500 19,501-26,000 26,001-33,000 33,001-40,000 40,001-50,000 50,001-60,000 60,001-80,000 80,001-100,000 100,001-130,000 >=130,001	Null < 2.0 liters 2.1-2.5 liters 2.6-3.0 liters 3.1-3.5 liters 3.6-4.0 liters 4.1-5.0 liters > 5.0 liters

This contrasts to the emission rates used for criteria pollutants, which use a broader set of criteria (Table 1-3).

Table 1-3 – Contrasting Criteria Pollutants and Energy in MOVES2010

Criteria Pollutants	Energy
Fuel type	***Fuel type***
Engine Technology	***Engine Technology***
Regulatory Class	Regulatory Class
Model Year Group	Model Year Group
Engine Size	***Engine Size***
Weight Class	***Weight Class***
Age Group	Age Group

Note: discriminators in bold, italic are used to classify that set of emissions in MOVES.

In MOVES2010, heavy duty vehicle running energy consumption was restructured without engine size and weight class sourcebin discriminators.[8] MOVES2010a extends this format to all combinations of sourcetypes and energy-related processes (start, running, extended idle). Removing two sourcebin discriminators significantly reduces the size of the database table, and pre-aggregating by engine size and vehicle weight shifts the size/weight calculations from MOVES onto external sources. A summary table of the changes to the energy sourcebin structure is presented below (Table 1-4).

Table 1-4 – Changes to Energy Sourcebin Discriminators between MOVES2010 and 2010a

Descriptors used in MOVES2010	Descriptors used in Moves2010a
Fuel type	Fuel type
Model year group (decadal)	Model year group (single year)
Engine size	Regulatory class
Vehicle Weight	
Size and weight distribution by sourcetype	
Engine Technology	

[8] Report: Development of Emission Rates for Heavy-Duty Vehicles in the Motor Vehicle Emissions Simulator MOVES2010 (EPA-420-B-12-049)

1.3 Structural Changes:

1.3.1 Updating the Database Sourcebinid Structure for Energy Rates

Seven database tables were changed to alter the sourcebin discriminators used for energy rates (Table 1-5). These changes aggregated the database so that size and weight were no longer distinguishing characteristics. The database was then re-disaggregated according to regulatory class.

As part of this process, the number of engine technologies in the MOVES database was reduced. This change altered four additional database tables (Table 1-5). The MOVES2010 engine technologies included hybrid varieties, fuel cell vehicles, and "advanced internal combustion" vehicles. These technologies were removed from the model, and the associated emission rates were removed from the emissionratebyage table.

Table 1-5 – Summary of Database Changes required

	Table Name	Change Summary
1	datasource	Added a new datasourceid that refers to this document.
2	emissionrate	Updated energy rates with new values and sourcebinids
3	emissionratebyage	Removed emission rates for enginetypeids other than conventional internal combustion (1) & electric (30)
4	fuelengfraction	Updated fuel and engine type combinations to remove enginetypes other than 1 & 30
5	enginetech	Removed engine technologies other than 1 & 30
6	fuelengtechassoc	Removed engine technologies other than 1 & 30
7	pollutantprocessmodelyear	Changed the energy polprocessids (9101,9102, 9190) to have single year modelyeargroupids (increase resolution of rates).
8	regclassfraction	Removed engine technologies other than 1 & 30.
9	samplevehiclepopulation	Reflects removal of sizeweightid and engine technologies (engtechid)
10	sizeweightfraction	Truncated
11	sourcetypepolprocess	Stopped requiring sizeweightid, and began requiring regclassid for energy polprocessids (9101, 9102, 9190) for all sourcetypes.

1.3.2 Converting MOVES2010 rates to the MOVES2010a structure

EPA created energy rates for the new sourcebin structure by aggregating the MOVES 2010 energy rates by regulatory class. For those regulatory classes that were mapped to a single source type, the conversion between the MOVES2010 structure and the MOVES2010a structure was a 1:1 correspondence. For those sourcetypeids that mapped to several regulatory classes (Table 1-6), the methodology is described below.

Table 1-6 – Mapping between Sourceusetypes and Regulatory Classes

SourcetypeID	Possible Regulatory Classes
11	10
21	20
31,32	30,41,42
41,43,51,52,53,54,61,62	46,47
42	46,48

Information from the 1997 and 2002 Vehicle Inventory and Use Survey (VIUS) as aggregated in the MOVES2010 database table samplevehiclepopulation (SVP) was used as a mapping tool between regulatory class and source type. The SVP table specifies the distribution of each source type and model year combination across fuel type, engine technology, SCCVtypeID,[9] engine size, vehicle weight, and regulatory class, with each row specifying a unique set of attributes. The SVP table was joined to the emissionrate table so that an additional column was added to the SVP with the corresponding MOVES2010 energy emission rate. This process was repeated for start rates, running rates, and extended idle rates. This produced a set of SVP tables, each with an additional emission rate column for the relevant process.

In order to create emission rates by regulatory class, we weighted each emission rate attached to the SVP table using year 0 populations from the sourcetypeagepopulation table of the MOVES execution database. The sales for each source type model year combination were distributed to the appropriate row of the SVP using the SVP stmyfraction column. Using the sales-based weighting, the emission rates were aggregated by regulatory class, fuel type, and model year. For start rates, this process was executed for operating mode 108, which is a cold start. The other seven start operating modes are modifications of a cold start with different soak times. As in previous version of MOVES, soak time effects derived from a California Air Resources Board report on uncatalyzed hydrocarbon emissions[10] were applied to develop the other seven operating modes (101,102, 103,104,105,106,107).

For running rates, the process outlined above was necessary only for motorcycles, passenger cars, passenger trucks, and light commercial trucks. The running rates for other sourcetypes already had been set to be a single set of rates in MOVES2010.[11] This process was repeated for each operating mode.

In MOVES, only sourcetypeid 62 (long-haul combination truck) has extended idle operation. Therefore, both regulatory class 46 (Medium Heavy Duty (19.5K lbs < GVWR < 33K lbs)) and regulatory class 47 (Heavy Heavy Duty (GVWR > 33K lbs)) were set to have the same extended idle rate as MOVES2010 sourcetypeid 62 vehicles.

[9] An SCCvtype, or source classification code vehicle type, is an alternative vehicle identification scheme which is used in the MOVES model.

[10] Methodology For Calculating And Redefining Cold And Hot Start Emissions, S. Sabate, March 1996

[11] These changes to the heavy duty energy rates are described in the heavy duty vehicles emission rate report. All heavy duty vehicles uses the same energy rates, but are differentiated by drive cycle and weight. Therefore, the vehicle specific power (VSP) distribution of these vehicles differs.

1.3.3 Changes to Engine Technologies

Engine technologies other than conventional internal combustion are not used substantially in the MOVES2010 default database. While these engine technologies each have different energy rates (Table 1-7), emission rates for pollutants other than energy are either set equivalent to the rate for conventional internal combustion vehicles or to zero.[12,13] Therefore, "conventional internal combustion" in the MOVES2010 database is effectively a description of all engine types other than electric for non-energy emissions. In recognition of this convention, we removed all engine technologies other than conventional and electric from the MOVES2010a database.

Table 1-7 – Engine Technologies in MOVES2010

engTechID	Engine Technology Name	In MOVES2010a
1	Conventional Internal Combustion	YES
2	Advanced Internal Combustion	
11	Moderate Hybrid - Conventional Internal Combustion	
12	Full Hybrid - Conventional Internal Combustion	
20	Hybrid - Advanced Internal Combustion	
21	Moderate Hybrid - Advanced Internal Combustion	
22	Full Hybrid - Advanced Internal Combustion	
30	Electric	YES
40	Fuel Cell	
50	Hybrid - Fuel Cell	

As reflected in Table 1-7, the database tables were altered to reflect these changes. Additionally, the emission rates supporting these engine technologies (2.8 million rows) were removed from the 4 million row MOVES2010 emissionratebyage table. Approximately 8,600 rows were removed from the emissionrate table.

1.4 Updating Energy Rates

After modifying the database structure and populating it with transformed energy rates, several additional changes were made. The 2008 and newer model year light duty vehicles (regulatory classes 20 and 30) were updated based on new data (model year 2008-2009) and rulemaking projections (model year 2010+). We also updated the energy emission rates to reflect the 2011 CAFE rulemaking and the 2012-2016 Light Duty Greenhouse Gas (LD GHG) and CAFE rulemakings. A number of other minor changes were also made.[14,15]

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[12] As an example, advanced internal combustion engines have criteria emission rates equivalent to conventional internal combustion engines, but electric engines have criteria emission rates equaling zero.

[13] In Draft MOVES2009 and MOVES2010, sourcetypeid 31 and 32 have non-zero penetrations of engtechid 2 in model years 2008 and newer. In earlier model versions, engine tech 2 was used as a means of reaching the fuel economy targets set in the 2008-2011 CAFE light truck rule. The changes described in this document negate the need for the penetration of advanced engine technology.

[14] An error was corrected in light duty diesel energy starts. To fix the problem, start-emission rates for model year 2000 and newer light and medium duty diesel vehicles (reg class 20, 30, 41, &42) were set to the MY 1999 rate. This is an approximately 55% reduction from the corresponding rates in the MOVES2010 database. While a large

The new energy consumption rates were based on a top-down analysis whereby CO_2 emission rates output from MOVES were calibrated to projected CO_2 emission rates. CO_2 emissions were used due to their direct proportionality to energy consumption rates. We assume that the rulemakings affected the quantity of energy consumed, but not the distribution between operating modes, nor the ratio between start and running.[16] As a result, we adjusted the energy rates using simple ratios between the old emission rates and the new emission rates (Table 1-8). Baseline values were derived by running MOVES2010 at the national/annual level using an input database that produced emission output only for regulatory classes 20 and 30. Emission quantity was divided by vehicle miles traveled to determine emission rates.

Model year 2008 and model year 2009 data were drawn from EPA's "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2009" (EPA420-R-09-014). The "Lab" average CO_2 values for each model year were adjusted upward by 25% to reflect real world fuel consumption.[17] The gasoline vehicles were set to this value. As the CAFE rules regulate fuel consumption in miles per gallon and treat gasoline and diesel vehicles equally, diesel energy consumption rates were multiplied by approximately 1.15 in order to compensate for the greater energy density of diesel fuel. [18]

For model year 2011 through 2016, rates were derived from the model year 2012-2016 Light Duty Greenhouse Gas (LD GHG) rulemaking analysis. The projections used in MOVES2010a are based upon the same assumptions as used the emission modeling conducted for the LD GHG rule. Model year 2010 was interpolated as a midpoint between model year 2009 and 2011. Note that the regulatory standards for model year 2011 and newer are in a classification schema that differs from that used in MOVES2010a.[19] Using vehicle level data from the rulemaking, we reanalyzed the vehicles to match the MOVES2010a vehicle classification scheme. As a result of this difference in classification scheme, the average CO_2 emission rate shown in this document is not expected to match those in the regulatory documents.

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fraction of this particular process, light duty diesel energy consumption is approximately 3% of total light and medium duty energy consumption, and start emissions are approximately 3% of light and medium duty diesel energy consumption. The impact of this change on total light and medium duty energy consumption is approximately 0.05%.

[15] The 2008-2011 CAFE light truck rule was reflected in MOVES2010 through the use of advanced internal combustion vehicles. For MOVES2010a, we removed this engine technology and directly modified the energy rates for regclassid 30 to reflect the CAFE rules.

[16] Maintaining the same ratio between running and start energy consumption rates likely overstates the reductions to the start process, and may be revisited in future MOVES model versions. While some technologies that reduce energy consumption (ie, engine downsizing) reduce start energy consumption, many others (such as aerodynamic improvements) do not. As starts are a very small portion of total energy consumption, the choice of approach has little impact.

[17] Final Rulemaking: Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards (published May 7, 2010). In miles per gallon, there is approximately a 25% gap between laboratory measured and real world achieved fuel economies.

[18] The relative energy densities of diesel and gasoline fuel are approximately 129,000 btu/gallon and 115,000 btu/gallon respectively.

[19] In MYs 2011 and later, small SUVs are considered cars, rather than light trucks under the CAFE and GHG regulations.

Projected improvements in air conditioning system efficiency were included in the energy rates themselves rather than in a modification of the MOVES2010a air conditioning function. However, because the MOVES A/C adjustments are multiplicative, this change will also reduce the energy consumption from air conditioning.

For the model year 2011 CAFE standards, a 1.15x adjustment was made for diesel vehicles. For 2012 and beyond, the diesel vehicles were presumed to meet the same CO_2 standard as the gasoline vehicles.

Rates for model years after 2016 were set equivalent to model year 2016. The following tables (Table 1-9,Table 1-10,Table 1-11, & Table 1-12) show the g/mile rate for the laboratory combined Federal Test Procedure (FTP)/Highway Fuel Economy Test (HFET) driving schedules and on-road value equivalents. The tables showing on-road values are what were used to modify the model. Note that no source type is composed solely of regulatory class 30, and that these tables were produced using a set of user input files that isolate the output of this regulatory class.

Table 1-8 – Ratios used to develop new rates in MOVES2010a[20]

	Ratios Used			
	From MOVES2010 to MOVES2010a			
	Trucks		Cars	
	Gas	Diesel	Gas	Diesel
2008	0.904	0.723	0.981	1.007
2009	0.896	0.716	0.969	0.995
2010	0.898	0.717	0.985	1.011
2011	0.831	0.663	1.002	1.028
2012	0.790	0.550	0.919	0.823
2013	0.769	0.535	0.893	0.800
2014	0.747	0.519	0.868	0.777
2015	0.716	0.497	0.830	0.743
2016	0.677	0.470	0.782	0.700

[20] Note that these ratios were applied against the emissionrate table, and that the model year 2008-2011 light duty truck rule was reflected in MOVES2010 through an engine technology mix. Thus, the CO_2 output from MOVES2010 was actually quite a bit lower than these ratios would indicate.

Table 1-9 – Test Cycle MPG

	MPG - Test Cycle							
	MOVES2010				MOVES2010a			
	Trucks		Cars		Trucks		Cars	
	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
2008	20.5	16.4	29.7	26.7	22.7	22.7	30.5	30.5
2009	20.5	16.4	29.7	26.7	22.9	22.9	30.9	30.9
2010	20.6	16.4	29.8	26.7	22.9	22.9	30.4	30.4
2011	20.6	16.4	29.8	26.8	24.8	24.8	29.9	29.9
2012	20.7	16.5	29.9	26.8	26.1	29.9	32.7	37.4
2013	20.7	16.5	29.9	26.8	26.9	30.8	33.7	38.5
2014	20.7	16.5	30.0	26.8	27.7	31.7	34.7	39.7
2015	20.7	16.5	30.0	26.9	29.0	33.2	36.3	41.5
2016	20.8	16.5	30.0	26.9	30.7	35.1	38.5	44.1

Table 1-10 – On-road MPG

	MPG - On Road							
	MOVES2010				MOVES2010a			
	Trucks		Cars		Trucks		Cars	
	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
2008	16.4	13.1	23.8	21.3	18.1	18.1	24.4	24.4
2009	16.4	13.1	23.8	21.4	18.3	18.3	24.7	24.7
2010	16.5	13.1	23.8	21.4	18.3	18.3	24.3	24.3
2011	16.5	13.1	23.9	21.4	19.9	19.8	24.0	24.0
2012	16.5	13.2	23.9	21.4	20.9	23.9	26.2	30.0
2013	16.5	13.2	23.9	21.5	21.5	24.6	26.9	30.8
2014	16.6	13.2	24.0	21.5	22.2	25.4	27.7	31.8
2015	16.6	13.2	24.0	21.5	23.2	26.5	29.0	33.2
2016	16.6	13.2	24.0	21.5	24.5	28.1	30.8	35.3

Table 1-11 – Test-Cycle CO_2

	CO2 - Test Cycle							
	MOVES2010				MOVES2010a			
	Trucks		Cars		Trucks		Cars	
	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
2008	433.9	621.8	299.2	381.9	392.0	449.4	291.4	333.7
2009	432.9	621.0	298.7	381.3	388.0	444.8	287.6	329.4
2010	431.9	620.1	298.3	380.8	388.0	444.8	292.0	334.5
2011	431.1	619.4	297.8	380.4	358.1	410.5	296.8	339.9
2012	430.3	618.7	297.4	380.0	339.9	340.2	271.9	271.9
2013	429.6	618.1	297.0	379.6	330.6	330.9	264.1	264.1
2014	429.0	617.5	296.7	379.2	320.5	320.8	256.4	256.4
2015	428.4	617.0	296.4	378.9	306.6	306.9	245.0	245.0
2016	427.8	616.5	296.1	378.6	289.6	289.9	230.6	230.6

Table 1-12 – On-road CO_2

	CO2 - On Road							
	MOVES2010				MOVES2010a			
	Trucks		Cars		Trucks		Cars	
	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel
2008	542.3	777.3	374.1	477.3	490.0	561.7	364.2	417.2
2009	541.1	776.2	373.4	476.7	485.0	556.0	359.5	411.8
2010	539.9	775.2	372.8	476.1	485.0	556.0	365.0	418.1
2011	538.9	774.2	372.3	475.5	447.6	513.1	370.9	424.9
2012	537.9	773.4	371.7	475.0	424.9	425.3	339.8	339.8
2013	537.0	772.6	371.3	474.5	413.2	413.6	330.1	330.1
2014	536.2	771.9	370.8	474.0	400.6	401.0	320.5	320.5
2015	535.5	771.2	370.4	473.6	383.2	383.6	306.3	306.3
2016	534.8	770.6	370.1	473.2	362.0	362.3	288.2	288.2

Following the conventions in MOVES2010, for all years, electricity, E85 (85% ethanol/gasoline blends), and compressed natural gas (CNG) energy consumption rates were set equal to gasoline. Based on MOVES2010, CNG start energy rates were set equal to the gasoline rates for starts multiplied by 1.05

1.5 Inventory Impacts of Changes relative to MOVES2010

The structural changes described in this document had little impact on model results. For any pollutant, national annual scale runs conducted for calendar year 2001 with the new database differ by less than 0.1% as compared to MOVES2010. A few specific processes related to energy differ by greater amounts (<10%), but have insignificant impact on total inventories. With one exception, there are no changes in processes unrelated to energy.[21]

The data changes, which reflect new data and the model year 2012-2016 LD GHG rulemaking, impact the results to a greater extent than the structural changes. As described above, we conducted national annual runs in order to estimate the impact of the database changes. The structural changes were evaluated with a national annual run in calendar year 2001. Calendar year 2001 was chosen because it predates any of the new data in the database. A second run was conducted in calendar year 2021 to assess the impact of the new data and projections for model year 2008 and newer. The MOVES runs were conducted with all vehicle types and all fuel types.

[21] Ammonia (NH_3) emissions also increase with the new database. The MOVES2010 database did not have NH_3 emission rates for engine technologies other than conventional internal combustion. Therefore the advanced internal combustion light trucks in MOVES2010 erroneously did not produce NH_3 emissions. MOVES2010a fixes this issue.

Table 1-13 – Fuel/Pollutant/Process affected in Calendar Year 2001

Fuel Affected	Pollutant Affected	Pollutant (Text)	Processes Affected	Process (Text)	% Change
CNG	90	CO2	2	Starts	-8%
CNG	91	Energy	2	Starts	-8%
CNG	93	Energy	2	Starts	-8%
Diesel	115	PM2.5 - Sulfate	2	Starts	-4%
Diesel	105	PM10 - Sulfate	2	Starts	-4%
Diesel	31	SO2	16	Crankcase - Starts	-4%
Diesel	90	CO2	2	Starts	-4%
Diesel	105	PM10	16	Crankcase - Starts	-4%
Diesel	115	PM2.5	16	Crankcase - Starts	-4%
Diesel	91	Energy	2	Starts	-4%
Diesel	92	Energy	2	Starts	-4%
Diesel	93	Energy	2	Starts	-4%
Diesel	31	SO2	2	Starts	-4%
Diesel	98	CO2	2	Starts	-4%
CNG	98	CO2	2	Starts	-2%
Gasoline	105	PM10- Sulfate	16	Crankcase - Starts	-1%
Gasoline	115	PM2.5- Sulfate	16	Crankcase - Starts	-1%
Gasoline	115	PM2.5- Sulfate	2	Starts	-1%
Gasoline	105	PM10- Sulfate	2	Starts	-1%
Gasoline	92	CO2	2	Starts	-1%
Gasoline	31	SO2	2	Starts	-1%
Gasoline	90	Energy	2	Starts	-1%
Gasoline	93	Energy	2	Starts	-1%
Gasoline	91	Energy	2	Starts	-1%
Gasoline	31	SO2	16	Crankcase - Starts	-1%

The calendar year 2001 results shown in Table 1-13 are driven by the modification of the energy rate sourcebins from a size/weight basis to a regulatory class basis. These effects are minimal on most pollutants and processes. Specifically, the organizational changes to the database had no effect on heavy duty running rates, which had already been aggregated in this manner. It also had minimal effect on those source types (passenger cars and motorcycles), which have a 1:1 to relationship with regulatory class. All the processes listed above are related to starts, which have a relatively small impact on total energy consumption.

Passenger truck and light commercial trucks are the only source types that were composed of similar regulatory classes in MOVES 2010 but different size/weight distributions. As a result, post-aggregation, the revised energy rates for each of these vehicles converged into a population weighted average of the two sets of energy rates. In regulatory class 30, the diesel fuel type is dominated by light commercial trucks, while the gasoline fuel type is dominated by passenger trucks. For further detail, a narrower light truck inventory comparison between MOVES2010 and MOVES2010a is shown below for calendar year 2007 (Table 1-14):

Table 1-14 – Comparison of National CO_2 Inventories in Calendar Year 2007 (Million Metric Tons)

	MOVES2010	MOVES2010a	Difference Percentage
Gasoline Passenger Truck	400.6	415.0	3.6%
Gasoline Light Commercial Truck	132.2	122.7	-7.2%
Diesel Passenger Truck	10.2	9.8	-4.7%
Diesel Light Commercial Truck	22.6	23.0	1.9%
Total	565.6	570.4	0.9%

In the second MOVES test run (calendar year 2021), we evaluated the impact of the energy rate updates (Table 1-15). As the scope of the impacts is larger, the table below is aggregated by emission process in order to show impacts by fuel and pollutant. Decreases are seen in energy related pollutants such as PM sulfate, energy and CO_2, SO_2. Smaller reductions are seen in ethanol emissions, as well as those emissions related to refueling and spillage.

Table 1-15 – Impacts of Changes in Calendar Year 2021

Fuel Affected	Pollutant Affected	Pollutant (Text)	% Change
Gasoline	115	PM2.5 - Sulfate	-14%
Gasoline	105	PM10 - Sulfate	-14%
Gasoline	92	Energy	-14%
Gasoline	91	Energy	-14%
Gasoline	93	Energy	-14%
Gasoline	90	CO2	-14%
Gasoline	31	SO2	-14%
Gasoline	98	CO2	-14%
Gasoline	21	Ethanol	-5%
Gasoline	87	VOC	-2%
Gasoline	80	NMOG	-2%
Gasoline	79	NMHC	-2%
Gasoline	86	TOG	-2%
Gasoline	1	THC	-2%
Diesel	92	Energy	-1%
Diesel	93	Energy	-1%
Diesel	91	Energy	-1%
Diesel	90	CO2	-1%
Diesel	98	CO2	-1%
Diesel	105	PM10	-1%
Diesel	115	PM2.5	-1%
Diesel	31	SO2	-1%
Gasoline	5	Methane	1%
Diesel	30	NH3[22]	7%
Gasoline	30	NH3	25%

[22] As noted in 21 above, this increase in ammonia emissions is due to a related fix.

2 Methane and N2O in MOVES2010

In MOVES2004, EPA based its estimates of emissions of methane (CH_4) and nitrous oxide (N_2O) on test results of the Federal Test Procedure (FTP) and the then current version of EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks." For Draft MOVES2009, EPA used both an enlarged database of test results plus a newer version of EPA's "Sources and Sinks" report[23] (primarily Table A-88 of its Annex 3).

EPA used the estimates from its "Sources and Sinks" report to fill holes its test data (i.e., when either no or limited results from Federal Test Procedure (FTP) were available).

Emission rates for N_2O and for CH_4 in Draft MOVES2009 were estimated for engine starts and for running operation and were not calculated for individual operating modes. This is in contrast to rates for other pollutants (e.g., HC, CO, NO_X) for which running emissions are calculated for each of 23 operating modes (based on vehicle speed and power) and for which start emissions are calculated for each of 8 operating modes (based on vehicle soak time prior to engine start).

Differences Between MOVES and "Sources and Sinks"

EPA publishes an annual report of emissions of greenhouse gases ("Inventory of U.S. Greenhouse Gas Emissions and Sinks"). Although the basic emission rates in EPA's "Sources and Sinks" report are based on technology groups, the basic emission rates in MOVES are based on (among other parameters) model year groups. Therefore , the initial analysis was to estimate emission rates by technology groups and then to convert those to model year groups. The conversion from technology groups to individual model years was based on the distribution of the individual technologies in each model year as detailed in the "Sources and Sinks" report (Tables A-84 through A-87 of the 2008 publication).

A second difference between those sets of rates is that the rates in EPA's "Sources and Sinks" report are estimates of emissions over the entire FTP driving cycle (in grams per mile) including the engine start while those in MOVES are given separately for starts (grams per start) and running operation (grams per hour).

To estimate running emission rates of N_2O and CH_4 in the draft MOVES2009 model, EPA used the same approach that it used in the analysis for the MOVES2004 model. That is, EPA assumed that the hourly emissions rate for the Bag-2 portion of the FTP is representative of the overall running rate (in grams per hour). To calculate this rate, EPA multiplied the Bag-2 emissions (in grams per mile) by the average speed of Bag-2 (i.e., 16.023 miles per hour), which produces the requisite emission rate (in units of grams per hour).

[23] "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2006," EPA Report No. EPA 430-R-08-005, April 2008. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Multiplying that hourly rate by the duration of the full LA-4 driving cycle (i.e., 1,372 seconds or 0.381111 hours) yields the total estimated running emissions of the LA-4 (or FTP) in grams. Then, multiplying the composite FTP emissions (in grams per mile) by the length of the LA-4 driving cycle (7.45 miles) yields the estimated total emissions (in grams) produced during the FTP. Subtracting those two quantities (total grams emitted during the FTP minus the total grams from the running emissions) yields an estimate of the emissions (in grams) from a generic start (57 percent hot-start and 43 percent cold-start).

It is these two rates (running emissions in grams per hour and generic start emissions in grams per start) that EPA used in the MOVES2004 model and updated in the Draft MOVES2009 model.

2.1 Nitrous Oxide Emission Rates:

Table 3-1 compares the nitrous oxide FTP emission rates (by technology group) from EPA's "Sources and Sinks" report, the comparable rates from MOVES2004, and the means of test data obtained from a study by Environment Canada.[24]

Table 2-1: Comparison of FTP Nitrous Oxide Emissions (grams / mile)

Vehicle Type / Control Technology	"Sources & Sinks" Rpt	MOVES2004	FTP Data
Gasoline Passenger Cars			
EPA Tier 2	0.0036	0.012	0.0050
LEVs	0.0150	0.012	0.0101
EPA Tier 1	0.0429	0.030	0.0283
EPA Tier 0	0.0647	0.054	0.0538
Oxidation Catalyst	0.0504	0.042	---
Non-Catalyst Control	0.0197	0.017	---
Uncontrolled	0.0197	0.017	---
Gasoline Light-Duty Trucks			
EPA Tier 2	0.0066	0.009	---
LEVs	0.0157	0.009	0.0148
EPA Tier 1	0.0871	0.067	0.0674
EPA Tier 0	0.1056	0.090	0.0370
Oxidation Catalyst	0.0639	0.054	0.0906
Non-Catalyst Control	0.0218	0.019	---
Uncontrolled	0.0220	0.019	---
Gasoline Heavy-Duty Vehicles			
EPA Tier 2	0.0134	0.019	---
LEVs	0.0320	0.019	---
EPA Tier 1	0.1750	0.138	---
EPA Tier 0	0.2135	0.183	0.0814
Oxidation Catalyst	0.1317	0.113	---
Non-Catalyst Control	0.0473	0.041	---
Uncontrolled	0.0497	0.043	---

[24] "Greenhouse Gas Emissions from 1997-2005 Model Year Light Duty Vehicles," Environment Canada Report No. ERMD Report #04-44.

Comparison of FTP Nitrous Oxide Emissions (grams / mile) *Con't*

Vehicle Type / Control Technology	"Sources & Sinks" Rpt	MOVES2004	FTP Data
Diesel Passenger Cars			
Advanced	0.0010	0.001	---
Moderate	0.0010	0.001	---
Uncontrolled	0.0012	0.001	---
Diesel Light-Duty Trucks			
Advanced	0.0015	0.002	---
Moderate	0.0014	0.002	---
Uncontrolled	0.0017	0.002	---
Diesel Heavy-Duty Vehicles			
Advanced	0.0048	0.005	0.0049
Moderate	0.0048	0.005	---
Uncontrolled	0.0048	0.005	---
Motorcycles			
Non-Catalyst Control	0.0069	0.007	---
Uncontrolled	0.0087	0.009	---

Twenty-two of the thirty-two technology groups contain no FTP N_2O test data. For those rates, we use the "Sources and Sinks" data.

In the following table, we take those 32 composite FTP N_2O rates (22 based on the "Sources and Sinks" rates and the remaining 10 based on newer FTP test data) and disaggregate them into running rates (in grams per hour) and start rates (in grams per generic start).

Table 2-2: Separating Composite FTP N_2O Emissions into Running and Start

Vehicle Type / Control Technology	FTP Comp (g / mile)	Running (g / hour)	Start (g / start)
Gasoline Passenger Cars			
EPA Tier 2	0.0050	0.0399	0.0221
LEVs	0.0101	0.0148	0.0697
EPA Tier 1	0.0283	0.2316	0.1228
EPA Tier 0	0.0538	0.6650	0.1470
Oxidation Catalyst	0.0504	0.6235	0.1379
Non-Catalyst Control	0.0197	0.2437	0.0539
Uncontrolled	0.0197	0.2437	0.0539
Gasoline Light-Duty Trucks			
EPA Tier 2	0.0066	0.0436	0.0325
LEVs	0.0148	0.0975	0.0728
EPA Tier 1	0.0674	0.6500	0.2546
EPA Tier 0	0.0370	0.2323	0.1869
Oxidation Catalyst	0.0906	0.8492	0.3513
Non-Catalyst Control	0.0218	0.2044	0.0845
Uncontrolled	0.0220	0.2062	0.0853
Gasoline Heavy-Duty Vehicles			
EPA Tier 2	0.0134	0.1345	0.0486
LEVs	0.0320	0.3213	0.1160
EPA Tier 1	0.1750	1.7569	0.6342
EPA Tier 0	0.0814	0.8172	0.2950
Oxidation Catalyst	0.1317	1.3222	0.4773
Non-Catalyst Control	0.0473	0.4749	0.1714
Uncontrolled	0.0497	0.4990	0.1801

Separating Composite FTP N_2O Emissions into Running and Start *Con't*

Vehicle Type / Control Technology	**FTP Comp (g / mile)**	**Running (g / hour)**	**Start (g / start)**
Diesel Passenger Cars			
Advanced	0.0010	0.0168	0.0010
Moderate	0.0010	0.0168	0.0010
Uncontrolled	0.0012	0.0202	0.0012
Diesel Light-Duty Trucks			
Advanced	0.0015	0.0253	0.0015
Moderate	0.0014	0.0236	0.0014
Uncontrolled	0.0017	0.0286	0.0018
Diesel Heavy-Duty Vehicles			
Advanced	0.0049	0.0828	0.0051
Moderate	0.0048	0.0809	0.0049
Uncontrolled	0.0048	0.0809	0.0049
Motorcycles			
Non-Catalyst Control	0.0069	0.0854	0.0189
Uncontrolled	0.0087	0.1076	0.0238

2.2 Methane Emission Rates:

The following table (table 3-3) compares the methane FTP emission rates (by technology groups) from the EPA's "Sources and Sinks" report, the rates from MOVES2004, and the means of the Environment Canada test data.

Table 2-3: Comparison of FTP Methane Emissions (grams / mile)

Vehicle Type / Control Technology	"Sources & Sinks" Rpt	MOVES2004	FTP Data
Gasoline Passenger Cars			
EPA Tier 2	0.0173	0.013	0.0110
LEVs	0.0105	0.013	0.0083
EPA Tier 1	0.0271	0.020	0.0242
EPA Tier 0	0.0704	0.066	0.0665
Oxidation Catalyst	0.1355	0.133	0.1351
Non-Catalyst Control	0.1696	0.162	0.1568
Uncontrolled	0.1780	0.171	---
Gasoline Light-Duty Trucks			
EPA Tier 2	0.0163	0.017	---
LEVs	0.0148	0.017	0.0117
EPA Tier 1	0.0452	0.034	0.0357
EPA Tier 0	0.0776	0.071	0.0708
Oxidation Catalyst	0.1516	0.143	0.1413
Non-Catalyst Control	0.1908	0.184	0.0390*
Uncontrolled	0.2024	0.195	---
Gasoline Heavy-Duty Vehicles			
EPA Tier 2	0.0333	0.034	---
LEVs	0.0303	0.034	---
EPA Tier 1	0.0655	0.047	0.0515
EPA Tier 0	0.2630	0.218	0.2487
Oxidation Catalyst	0.2356	0.208	0.2135
Non-Catalyst Control	0.4181	0.403	---
Uncontrolled	0.4604	0.445	---

***** Possible outlier (single test vehicle).

Comparison of FTP Methane Emissions (grams / mile) *Con't*

Vehicle Type / Control Technology	"Sources & Sinks" Rpt	MOVES2004	FTP Data
Diesel Passenger Cars			
Advanced	0.0005	0.001	---
Moderate	0.0005	0.001	---
Uncontrolled	0.0006	0.001	---
Diesel Light-Duty Trucks			
Advanced	0.0010	0.001	---
Moderate	0.0009	0.001	---
Uncontrolled	0.0011	0.002	---
Diesel Heavy-Duty Vehicles			
Advanced	0.0051	0.004	0.0039
Moderate	0.0051	0.004	---
Uncontrolled	0.0051	0.004	---
Motorcycles			
Non-Catalyst Control	0.0672	0.067	---
Uncontrolled	0.0899	0.090	---

Note that 17 of the 32 technology groups have no FTP CH_4 test data. For those rates, the "Sources and Sinks" data for the FTP rates were used. Also, for non-catalyst light-duty gasoline trucks, there was only one FTP result, and that single FTP methane result appears to be an outlier (i.e., too low). Therefore, for that technology group we also used the "Sources and Sinks" rate.

In the following table (Table 3-4), those 32 composite FTP CH_4 rates (18 based on the "Sources and Sinks" rates and the remaining 14 based on newer FTP test data) were disaggregated into running rates (in grams per hour) and start rates (in grams per generic start).

Table 2-4: Separating Composite FTP CH_4 Emissions into Running and Start

Vehicle Type / Control Technology	FTP Comp (g / mile)	Running (g / hour)	Start (g / start)
Gasoline Passenger Cars			
EPA Tier 2	0.0110	0.1131	0.0386
LEVs	0.0083	0.0632	0.0379
EPA Tier 1	0.0242	0.3164	0.0596
EPA Tier 0	0.0665	0.9952	0.1165
Oxidation Catalyst	0.1351	2.1613	0.1831
Non-Catalyst Control	0.1568	2.3654	0.2666
Uncontrolled	0.1780	2.6855	0.3026
Gasoline Light-Duty Trucks			
EPA Tier 2	0.0163	0.1114	0.0790
LEVs	0.0117	0.0801	0.0568
EPA Tier 1	0.0357	0.3775	0.1223
EPA Tier 0	0.0708	0.9788	0.1544
Oxidation Catalyst	0.1413	2.0255	0.2808
Non-Catalyst Control	0.1908	0.4807	0.1071
Uncontrolled	0.2024	2.4970	0.5563
Gasoline Heavy-Duty Vehicles			
EPA Tier 2	0.0333	0.3111	0.1295
LEVs	0.0303	0.2831	0.1179
EPA Tier 1	0.0515	0.4816	0.2005
EPA Tier 0	0.2487	3.6353	0.4674
Oxidation Catalyst	0.2135	2.8555	0.5026
Non-Catalyst Control	0.4181	5.5908	0.9841
Uncontrolled	0.4604	6.1565	1.0837

Separating Composite FTP CH_4 Emissions into Running and Start *Con't*

Vehicle Type / Control Technology	**FTP Comp (g / mile)**	**Running (g / hour)**	**Start (g / start)**
Diesel Passenger Cars			
Advanced	0.0005	0.0098	0.0000
Moderate	0.0005	0.0098	0.0000
Uncontrolled	0.0006	0.0117	0.0000
Diesel Light-Duty Trucks			
Advanced	0.0010	0.0195	0.0000
Moderate	0.0009	0.0176	0.0000
Uncontrolled	0.0011	0.0215	0.0000
Diesel Heavy-Duty Vehicles			
Advanced	0.0039	0.0765	0.0000
Moderate	0.0051	0.0997	0.0000
Uncontrolled	0.0051	0.0997	0.0000
Motorcycles			
Non-Catalyst Control	0.0672	1.0138	0.1143
Uncontrolled	0.0899	1.3563	0.1528

2.3 Alternative Fuels

Since no additional FTP data were available, the emission rates of N_2O and CH_4 in the draft MOVES2009 model are based entirely on EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2006" (Table A-89 of its Annex 3). Those FTP rates from that report are reproduced in the following table (Table 3-5):

Table 2-5 Composite FTP Emissions from Alternative Fuels

Vehicle Type / Fuel Type	N_2O (g / mile)	CH_4 (g / mile)
Light-Duty Vehicles		
Methanol	0.067	0.018
CNG	0.050	0.737
LPG	0.067	0.037
Ethanol	0.067	0.055
Biodiesel (BD20)	0.001	0.000
Heavy-Duty Vehicles		
Methanol	0.175	0.066
CNG	0.175	1.966
LNG	0.175	1.966
LPG	0.175	0.066
Ethanol	0.175	0.197
Buses		
Methanol	0.175	0.066
CNG	0.175	1.966
Ethanol	0.175	0.197

Disaggregating those composite FTP rates into start and running rates yields the following results:

Table 2-6: Methane Emission Rates from Alternative Fuels

Vehicle Type / Fuel Type	Running (g / hour)	Starts (g / start)
Light-Duty Vehicles		
Methanol	0.2192	0.0506
CNG	8.9755	2.0700
LPG	0.4506	0.1039
Ethanol	0.6698	0.1545
Heavy-Duty Vehicles & Buses		
Methanol	0.8038	0.1854
CNG	23.9429	5.5218
LNG	23.9429	5.5218
LPG	0.8038	0.1854
Ethanol	2.3992	0.5533

Table 2-7: Nitrous Oxide Emission Rates from Alternative Fuels

Vehicle Type / Fuel Type	Running (g / hour)	Starts (g / start)
Light-Duty Vehicles		
Methanol	0.6431	0.2541
CNG	0.4799	0.1896
LPG	0.6431	0.2541
Ethanol	0.6431	0.2541
Heavy-Duty Vehicles & Buses		
Methanol	1.6797	0.6636
CNG	1.6797	0.6636
LNG	1.6797	0.6636
LPG	1.6797	0.6636
Ethanol	1.6797	0.6636

3 Updates to the Methane Rates for MOVES 2010a

For MOVES2010a, the MOVES calculations to derive methane (CH_4) from total hydrocarbons (THC) values were updated, rather than as a separate emission rate as in earlier versions of the model. This change more closely aligns the methane calculations with the calculation of other hydrocarbon compounds in MOVES. As an example, volatile organic compounds (VOCs) are calculated in a chained (multiplicative) manner rather than as independent emission rate. Similarly, the chained calculation of methane is based upon the assumption of a direct relationship between CH_4 and THC by age, vehicle type, and fuel. As seen earlier in this report, those vehicles that tend to have higher THC (such as heavy duty vehicles) also tend to have higher methane emissions.

In the MOVES calculations, methane must be removed from the THC inventory in order to calculate values for other hydrocarbon species needed in air quality analysis. However, as the standalone methane emission rates were neither age nor temperature sensitive, there were some disconnects between THC and methane (where THC varied with age and temperature, but methane did not). "Chaining" the calculation of methane emissions to THC values allows EPA to make these improvements to the methane inventory, as well.

Additionally, connecting THC and methane removes a potential issue where methane emissions could have exceeded THC emissions. Where THC and CH_4 are both calculated independently in MOVES2010 and earlier MOVES versions, MOVES could calculate a negative amount for these other compounds, which is physically not possible.

In MOVES2010a, CH4 is calculated by applying a multiplicative factor (CH4THCRAtio in the MethaneTHCRatio table) to the calculated THC value after all adjustments to THC have been made for all fuel types. Once the CH4 value has been determined, CH4 is used in MOVES as it was before in all further calculations.

To create the new rates for pre-model year 2003 vehicles, methane and THC Emission rates for all gasoline and diesel vehicles were read from the movesoutput file and the ratio is computed. Light duty vehicle, light duty truck, and heavy duty gasoline vehicles were the only source types which were run. All of the other source types were filled with these data. Motorcycles were filled with light duty vehicle rates.

To create the new ratios for 2004 and newer vehicles, the MOVES 2010a rates were transferred from the MOVES2010 data using a process similar to that described above. The LDV rates are again used for the motorcycles.

The methane ratios for 2007 and newer model year diesel trucks were not taken from the MOVES2010 estimates. The constant value of 0.5846 was derived from new technology diesel vehicle emission testing done for the Health Effects Institute (HEI) Advanced Collaborative Emissions Study (ACES)[25].

[25] HEI ACES: Khalek, I., Bougher, T., and Merritt, P. M. 2009. Phase 1 of the Advanced Collaborative Emissions Study. Prepared by Southwest Research Institute for the Coordinating Research Council and the Health Effects Institute, June 2009. Available at www.crcao.org.

Methane ratios for ethanol are a constant value of 0.37 for the running and engine start processes and zero for all other processes. All raw gasoline evaporative methane ratios can be assumed to be zero since gasoline formulations typically contains negligible amounts of methane.