Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES201X

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1 Executive Summary

In MOVES, the fuel quality database tables are populated based on an aggregation of fuel survey data, as well as the extensive refinery gate batch dataset collected as a part of EPA compliance programs. We aggregate the data to 45 unique fuel property areas, generally representing the geographic distribution of refined products pipelines and taking into account state and local fuel programs. Fuel properties in MOVES are projected to calendar year 2060 using estimates from the Annual Energy Outlook[1,2] report.

MOVES includes the Fuel Wizard tool that allows users to adjust local fuel properties using EPA refinery modeling conducted for the Tier 3 Motor Vehicle Emissions and Fuel Standards rulemaking.[3] With this tool, states and local areas can streamline the process to analyze potential fuel control programs, such as RVP, by taking into account the changes to other fuel properties that would occur with these programs.

In MOVES201X, fuel region definitions have been updated to include state and local programmatic changes through the year 2015, and associated regional fuel properties have been updated to reflect new refinery compliance batch data through the same year. Additionally, the projection of E15 use beyond the year 2015 has been removed from the MOVES201X default database (the capability and effects of E15 use in the model remain unchanged). Finally, the Fuel Wizard tool has been permanently corrected to address a calculation error originally found in MOVES2014, and patched in the MOVES2014a November update.

2 Introduction

In the context of the MOVES model, a fuel supply refers to the regional distribution of specific fuel properties (e.g., sulfur content, RVP value, ethanol market share, etc.) for gasoline, diesel, and CNG fuels. This document describes the background and methodology used in developing the fuel supply components of MOVES, as well as the updates newly implemented in MOVES201X. For information regarding the effects of these properties on the emissions inventory, please see the MOVES Fuel Effects report[4] (for vehicle exhaust emission impacts) and the MOVES Evaporative Modeling report[5] (for vehicle evaporative impacts).

Section 3 provides background on the data and methodology used to develop the MOVES gasoline fuel supply.

Section 4 defines the large geographical areas used in MOVES fuel supplies. Section 5 discusses the aggregation of the disparate sources of data used in assigning properties to these areas, the adjustment to these properties for the inclusion of ethanol and other renewables, and the effects from local fuel control programs. Section 6 discusses the methodology of applying the AEO projections for renewable fuel (including E85), into future years. Section 7 describes the development of the fuel supply used in the nonroad component of the model. Finally, Section 8 describes the fuel wizard tool based on EPA refinery modeling data that can be used to adjust fuel properties in modeling local fuel control programs.

Both the fuel supply and fuel wizard in MOVES201X have been updated from MOVES2014a. The specifics and the emission impacts of these changes are discussed in Sections 6, 7, and 8.

3 Background

The technique for estimating gasoline fuel properties and their variation over seasons and years relies heavily on our nationwide refinery gate compliance data set[a], with supplementary information from local retail surveys. This data includes volumes and fuel properties used in MOVES calculations (e.g., RVP, sulfur, aromatics content, distillation values), the types of fuel (conventional gasoline (CG), reformulated gasoline (RFG), blendstock for oxygenate blending (BOB), as well as additional fuel property data (e.g., API gravity, batch type)). This data was used by EPA for the Tier 3 rulemaking analysis.[6] This dataset includes approximately 30,000 entries per year (each entry containing batch-specific properties), with EPA using the 2006-2015 calendar year data for the MOVES201X analysis.

After the initial aggregation of this compliance batch data, it became apparent that basing large geographic areas on a small number of point-source samples was inadequate, due to large batch-to-batch variations.

Figure 1 provides an example of the batch-to-batch variation that occurs for E200 (the percentage of fuel that evaporates at 200°F). E200 was specifically selected for this example due to its current status as an unregulated fuel property that nevertheless has a significant impact on exhaust emissions, based on the EPAct models (for more information, see the MOVES201X Fuel Effects report).[4]

[a] EPA collects electronic records of refinery fuel property data as it leaves the facility, for compliance purposes.

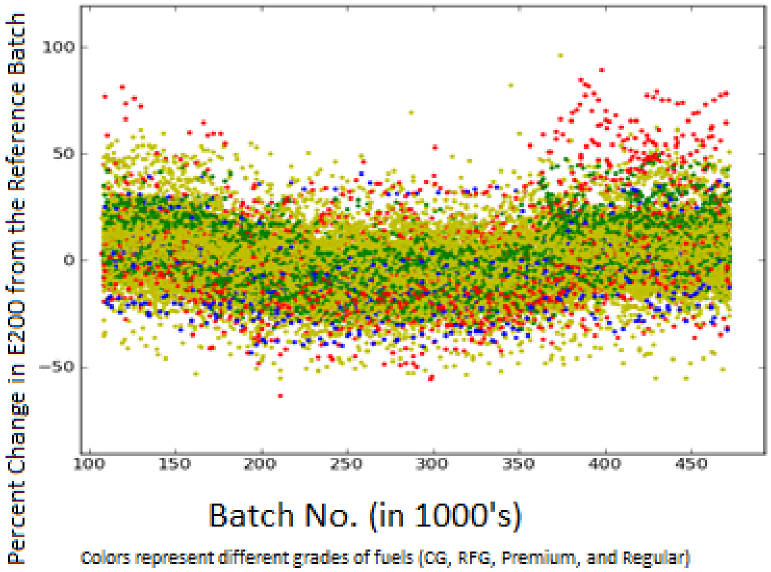

Figure 1 Example of Fuel Quality Variation (E200) from EPA Compliance Data

Of course, selecting any one of these points to represent an area as a whole would be inappropriate. In addition, due to the prevalence of downstream blending with multiple fuel deliveries, it would be unlikely that variations of this magnitude would be seen at a retail outlet (as multiple batches would tend to move the overall fuel qualities to the average). Therefore, we now use an aggregation methodology to take advantage of the large amount of data available from the EPA-collected compliance data, while also preserving the importance of downstream sampling from the Alliance of Automotive Manufacturers (AAM) and other sources, as well as applying the latest refinery modeling developed as part of the Tier 3 rulemaking process. With this methodology, we believe that the fuels contained in the default MOVES database 1) more closely represent actual in-use fuel qualities for a given area, 2) more closely represent the fuel variations from one local region to another, and 3) provide simplified interpretation of the fuel supply database for external users of the model.

4 Regional Fuels

Aggregating fuels into larger, more representative areas was the main goal in the development of the regional fuels approach. Using this methodology, we have created eleven general fuel regions for the United States and major territories. We initially based these fuel regions on existing Petroleum Administration Defense District (PADD) boundaries (a historic division of fuel supply areas originally developed in the 1950s), and then adjusted to account for broad fuel distribution corridors and the presence of bulk fuel pipelines and terminals. Terminal locations and their associated pipelines were identified using the Petroleum Terminal Encyclopedia provided by the Oil Price Information Service (OPIS).[7] For illustrative purposes, Figure 3 below shows the pipeline locations. Using these terminal locations, we could group areas sharing connections to similar pipeline networks. Within these broad fuel regions, we further identified areas requiring additional unique fuel qualities, due to federal, state, or local fuel quality standards.

Figure 2 An Example of Petroleum Product Pipelines in the Continental United States[8]

Although area-specific fuel region has not been specifically defined for the historical Geographic Phase-in Area (GPA), we have created a fuel region including the Rocky Mountain area closely related to this area. The GPA was historically used in MOVES to accurately represent small refiner allowances in the Tier 2 fuel program for a specific region, and is no longer necessary for modeling future fuel projections. Table 1 identifies and briefly describes each region in MOVES default fuel supply database. Additionally, please see Figure 4 for a graphical representation of these fuel regions, including areas adjusted from the large fuel region aggregates to account for state or local fuel control programs.

Table 1 Base Fuel Region ID Numbers and General Descriptions

Base Region ID#	Base Region Name	General Description
1	**East Coast**	East Coast states, west to Appalachians; Florida; and Gulf Coast region
2	**Midwest**	Midwest states, east to Appalachians; Tennessee; Kentucky
3	**South**	Iowa to Texas (North to South), Alabama to New Mexico (East to West); not including counties along the Gulf Coast;
4	**North**	North and South Dakota, Minnesota, Wisconsin
5	**Rocky Mtns.**	Pacific Northwest, Rocky Mountain states
6	**NV/AR/CA (CG only)/All Others**	California (CG Only)[b], Nevada, Arizona not using RFG, small market areas including Alaska, Hawaii, Puerto Rico and Virgin Islands
11	**East Coast RFG**	East Coast states and regions using RFG fuel or under a controlled fuel program
12	**MD/VA RFG**	Maryland and Virginia regions using RFG fuel or under a controlled fuel program
13	**Texas RFG**	Texas regions using RFG fuel or under a controlled fuel program
14	**Midwest RFG**	Midwest regions using RFG fuel or under a controlled fuel program
15	**California RFG**	California using California fuel, Nevada and Arizona regions using California fuel or California fuel derivatives

[b] Every California county is assumed to use California RFG, therefore Base Region 6 in MOVES does not include any market share in California.

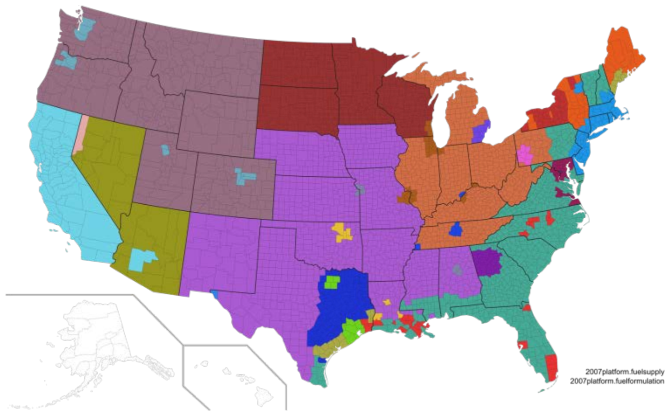

Figure 3 Fuel Regions in the MOVES Model

The regional fuel areas are defined by the RegionCounty table in the MOVES default database. This table contains the counties (countyID) included for each defined region (fuelRegionID) for a given year (fuelYearID), including regions with state or local fuel control programs.[c] The RegionCounty table also has an identifier (regionCodeID) which can be used to model separate fuel regions for onroad and nonroad fuel use.

The fuel properties associated with each of these regions are represented in another table, FuelFormulation, which is discussed in detail in Section 5 of this document. Furthermore, the FuelSupply table defines the market share fractions of various fuels sharing the same fuel region, such as E10, E15, E85, biodiesel, and CNG. For more information regarding the specific design and properties of these tables in MOVES201X, please refer to the MOVES Module Reference.[9]

The fuelRegionID field contains some information regarding the nature of the fuel region as part of the ID number, in an effort to make this table more easily readable by the user. The ID can be read as described below:

fuelRegionID: AABBCCDDXX

where: AA = base region ID (first digit dropped if zero)
BB = maximum summer region RVP value, or 00 for ASTM
CC = presence of RVP waiver
DD = presence of minimum ethanol level
XX = reserved for future use

[c] In MOVES201X, we updated the county to fuel region assignments based on updates to local fuel programs between 2013 (used in MOVES2014a) and 2015.

The contents of the fuelRegionID are shown in Table 2 below. The maximum summer RVP refers to the maximum Reid Vapor Pressure, which is a measure of the volatility of the fuel.[10,d] Local fuel programs set a limit to the vapor pressure of the gasoline fuel to reduce evaporative emissions of volatile organic compounds. If this value is 0, then we assume that the region is using the federal RVP requirements.[10]

The RVP waiver refers to the “1.0 psi RVP allowance for gasoline containing ethanol at 9 to 10 volume percent”.[10] Thus, for regions with an RVP waiver and a summer RVP limit of 7.8 psi, the RVP of an E10 fuel is assumed to be 8.8 psi. Not all fuel regions allow for the 1.0 psi fuel waiver; for example, a State Implementation Plan (SIP) may enforce an RVP standard that does not allow the 1.0 psi waiver. Thus, fuel regions may be distinguished by the presence or absence of an RVP waiver.

The minimum ethanol content field establishes a minimum ethanol level required either by RFG or local fuel programs.

[d] State-by-State RVP table with maximum RVP is located at the US EPA Reid Vapor Pressure webpage.[10]

Table 2 regionID Table in MOVES201X

fuelRegionID	AA, Base Region ID#	Base Region Name	BB, Maximum summer RVP (psi) or 0.0 for ASTM	CC, E10 RVP Waiver (00=1 psi waiver, 1=no waiver)	DD, Minimum ethanol volume, %	XX (Reserved for future use)
0	1	East Coast	0.0	0	0	0
100000000			0.0	0	0	0
100010000			0.0	1	0	0
170000000			7.0	0	0	0
178000000			7.8	0	0	0
178010000			7.8	1	0	0
200000000	2	Midwest	0.0	0	0	0
270000000			7.0	0	0	0
278000000			7.8	0	0	0
278010000			7.8	1	0	0
300000000	3	South	0.0	0	0	0
370000000			7.0	0	0	0
370010000			7.0	1	0	0
400000000	4	North	0.0	0	0	0
500000000	5	Rocky Mtns	0.0	0	0	0
578000000			7.8	0	0	0
600000000	6	CA/NV/AR/All Others	0.0	0	0	0
678000000			7.8	0	0	0
1170011000	11	East Coast RFG	7.0	1	10	0
1270011000	12	MD/VA RFG	7.0	1	10	0
1370011000	13	Texas RFG	7.0	1	10	0
1470011000	14	Midwest RFG	7.0	1	10	0
1570011000	15	California	7.0	1	10	0

In total, MOVES201X has 24 fuel regions. We may consider additional fuel regions in the future based on fuels data and recommendations from users. We are aware that fuel regions, and especially local and state fuel control programs, change over time, both historically and into the future. However, for the default fuel database in MOVES201X, we have chosen to keep the fuel regions consistent (a snapshot of the year 2015) through time. An update to this methodology allowing for historical and future variation in fuel region definitions is being considered for future versions of the MOVES model.

5 Fuel Properties

5.1 Gasoline

The EPA fuel compliance data consists of a set of databases, by year, which contain reports provided by refiners, downstream blenders, and terminal operators as part of their process to comply with EPA fuel regulations. This data is provided to EPA periodically, with a complete dataset for the previous year usually compiled in the subsequent year. These reports (and underlying databases) are considered Confidential Business Information (CBI) and cannot be provided as part of this document. For the regional fuel properties in MOVES201X, we chose to use 2006-2015 as analysis years, considering the completeness of these databases. Future updates to the MOVES fuel properties will take advantage of new compliance data as it becomes available.

The fuel compliance data includes information on fuel as it leaves its point of production (e.g., refinery) and contains fields for a multitude of properties as well as information regarding whether the fuel is being distributed as conventional gasoline, reformulated gasoline or as a blendstock for oxygenate blending (BOB). These reported properties form the basis for the fuel properties used in the regional fuel methodology, and are eventually aggregated into the fuel properties for the large fuel regions described in the previous section. The specific fuel properties contained in these batch data can be found in Table 3 below. A summary of EPA compliance batch data for years 1997-2015 has recently been compiled and made publicly available (see Appendix A).

Table 3 Properties Included in EPA Fuel Compliance Data

Batch Volume
Production Date
Batch Grade
VOC Control
Oxygen
Sulfur
Aromatics
Olefins
Benzene
Methanol
MTBE
Ethanol
ETBE
TAME
t-Butanol
RVP
T50
T90
E200
E300
API Gravity

Before aggregating to fuel regions, we processed the dataset to exclude duplicate reporting (e.g., a refinery and independent lab results may both report the same fuel). We also repaired or excluded batches with missing or inappropriate data (e.g., T90 can be correlated to E300, such that if a T90 value is missing for a batch of fuel but an E300 value is present, T90 can be estimated and included in the full dataset. See Equation 1 and Equation 2 below for correlation equations used for T50 and T90 gap filling, respectively). Finally, we separated differing types of fuel batches for further processing (i.e., conventional gasoline (CG) and pre-blended fuels can be included in the dataset without any adjustment, BOB fuels must be adjusted to account for oxygenates added downstream from the refinery gate). After these processing steps, we had a set of data containing between twenty and thirty-five thousand usable records of batch properties (depending on year), with no fuel region being represented by less than one thousand batches.

$$T_{50} = 2.0408163 \times (147.91 - E_{200}) \qquad \textbf{Equation 1}$$

$$T_{90} = 4.5454 \times (155.47 - E_{300}) \qquad \textbf{Equation 2}$$

These data were then aggregated by fuel region, using fuel batch size as a weighting factor. Initially, fuels were aggregated into four seasonal categories, including summer, winter, and two transitional ‘shoulder’ seasons. After reviewing the results of these categories, EPA determined that there was not adequate data (<100 batches for some regions) for the shoulder seasons to remain as separate categories, and, therefore, these data were re-aggregated into the summer and winter seasons. Additionally, because Tier 3 refinery modeling results (described later in this section) only provide adjustments for winter and summer seasons, we felt it was not appropriate to apply these adjustments to additional seasons at this time. The two aggregation seasons used for this dataset are summer (May, June, July, and August) and winter (January, February, March, April, September, October, November, and December).

Beginning with MOVES2014, MOVES contains a fuel effects model based on the EPAct/V2/E-89 (EPAct) gasoline fuel effects study.**Error! Bookmark not defined.** This work provides a modern representation of fuel effects in Tier 2 vehicles, but it was not designed to model the emission impacts of gasoline blends containing MTBE, ETBE or TAME. All MTBE fuels have been replaced with ethanol (E10) fuels in order to provide a functional approximation of fuel effects in years post-2001. The fuel parameters MTBE, ETBE and TAME have been removed entirely from the default database in MOVES201X and will no longer be accessible by the user. EPA recognizes that there is MTBE in use post-2001; however, MOVES201X is not currently capable of using different fuel effects models within the same calendar year, and EPA felt the value of properly modeling Tier 2 vehicles justifies the implementation of the more modern fuel effects model in this case.

In addition to the EPA compliance data, we also included downstream fuel sampling data measured by the AAM.[11] Because the AAM data represents only a snapshot of fuel properties at individual times and locations, it cannot represent fuel properties for a region on its own. However, it serves as an important validation to adjustments made to compliance data to account for BOB fuels, as well as the aggregate regional results used in the default fuel supply. Because this data is sampled at retail locations, it includes steps in the downstream fuel process that we cannot fully account for using only compliance data sampled at refineries. By including this downstream sample data as part of the validation process, we have increased our confidence that our final result is appropriately representing retail location samples for a given fuel region.

In support of the Tier 3 rulemaking (which included reductions in fuel sulfur content), refinery modeling tools were used to generate adjustments to secondary fuel properties affected by changes in sulfur, RVP, and ethanol level.[6] EPA understands that fuel property changes cannot happen independently, and has made an effort to capture these interactive effects in the MOVES fuel supply. The adjustments for sulfur, RVP, and ethanol level are shown in Table 4, Table 5 and Table 6. For example, the RVP adjustment factor in Table 4 increases the RVP by 1 psi when the ethanol is changed from E0 to E10, to account for the RVP 1 psi waiver discussed in Section 4.

Table 4 Adjustment Factors for Various Ethanol Blends

ETHANOL ADJUSTMENT FACTORS (from E0 to E10 or E15[e])										
FUEL	DESCRIPTION	RVP	SULF	AROM	OLEF	BENZ	E200	E300	T50	T90
E10 S	E10 Summer Fuel	1.00		-2.02	-0.46		3.11	0.39	-6.34	-1.77
E10 W	E10 Winter Fuel	1.00		-3.65	-2.07		4.88	0.54	-9.96	-2.45
E15 S	E15 Summer Fuel			-3.36	-1.64		9.24	0.91	-18.86	-4.14
E15 W	E15 Winter Fuel			-5.69	-3.27		11.11	1.01	-22.67	-4.59

Table 5 Adjustment Factors for Lower RVP Blends

RVP ADJUSTMENT FACTORS (per PSI)										
FUEL	DESCRIPTION	RVP	SULF	AROM	OLEF	BENZ	E200	E300	T50	T90
per PSI	Boutique fuel adj.	-1.00					-1.26	-0.50	2.57	2.27

Table 6 Adjustment Factors for Lower Sulfur Blends

SULFUR ADJUSTMENT FACTORS (per ppm)										
FUEL	DESCRIPTION	RVP	SULF	AROM	OLEF	BENZ	E200	E300	T50	T90
per ppm	Sulfur fuel adj.		-1.00	-0.032						

Table 7 shows the gasoline sulfur levels used in MOVES201X for 2006 and later years. In MOVES default, we assume gasoline fuels in all regions meet the requirements of 10 ppm sulfur fuel of the Tier 3 program starting in 2017.[3] For calendar years between 2006 and 2016, we used the batch fuel data as the source of the fuel sulfur content. For these years, the sulfur levels of conventional gasoline and E10 vary between base fuel regions.

[e] The default fuel supply in MOVES201X does not contain any E15 market share. However, these values have been retained in the Fuel Wizard for use in the creation on user-specific E15 fuel blends.

Table 7 Gasoline Fuel Sulfur Content (ppm) Used in the Fuel Supply for Conventional Gasoline and Gasoline-ethanol Blends

	E0 through E15 gasoline-ethanol blends		E85 Blends
Calendar Years	All Base Regions (except California)	California (Base Region ID #15)[f]	All Base Regions
2006-2016	Yearly regional average based on compliance batch dataset	9	8
2017-2060	10		

We are aware that the presence of the sulfur averaging, banking and trading (ABT) program and the existence of Tier 3 early-compliance sulfur credits create additional volatility in fuel sulfur levels for the years 2017 through 2020. The reduced fuel sulfur level due to early compliance is reflected in MOVES201X through the year 2015, where data regarding regional variation in sulfur level is available. Unfortunately, there is too much uncertainty associated with the individual refinery compliance decisions and the movement of fuel through the fuel distribution system to predict the in-use sulfur levels in specific geographic areas beyond calendar year 2015. Specifically, we recognize that individual areas may have fuel sulfur falling above or below the 10 ppm required by Tier 3 and assumed in MOVES201X for years 2017 and later. The MOVES Technical Guidance documentation (XX) will provide information regarding appropriate action in modeling those specific scenarios. The default fuel sulfur levels for years 2016 and later will be updated in future versions of MOVES as data becomes available.

Unfortunately, even though MOVES201X models the years 1990 and 1999-2060, batch fuel compliance data was not available for years prior to 2006 or after 2016 (records before this period exist in non-electronic form; for more information, see the 2005 Fuels Trends report).[12] Therefore, for the years 1990, 1999, and 2000-2005, we used county-specific fuel data contained in MOVES2010 as a surrogate for compliance data. These county-level fuel properties were aggregated into the new fuel regions in a similar way to the fuel compliance data, as described above, with weighting by county light-duty gasoline VMT. For most fuel property data after 2016, we assumed no change to the previous fuel properties until affected by statutory regulations, such as the Tier 3 sulfur program. As a result, the database will contain major fuel property changes in 2017, and then remain constant afterwards, as described in more detail in Section 6.

Of course, in reality, there will be various changes to fuel properties due to future market shifts that we are not able to predict. Therefore, as new fuel property information becomes available through EPA compliance reports as well as AAM fuel survey data, we will continue to update the default fuel supply in future MOVES versions.

[f] California is the only fuel region that has E5 fuel, which is assumed to have 9 ppm sulfur content, starting in 2007. In 2010, E5 is replaced with E10 fuel which also is assumed to have 9 ppm sulfur content.

In MOVES, the fuel property information described above is contained in the FuelFormulation table. This table contains all the fuel properties relevant to the fuel effects models (e.g., the Complex Model, the EPAct Model, and the Tier 2 Low Sulfur Model), including RVP, sulfurLevel, aromaticContent, olefinContent, benzeneContent, e200, e300, BioDieselEsterVolume, CetaneIndex[g], PAHContent[g], T50, and T90 as post-aggregated values for a given fuel region (or regional control program), for a given time period. Each set of these fuel formulations is given an ID (fuelFormulationID), and also assigned to a subtype of fuels to ease model calculations for similar fuel properties (fuelSubtypeID). The fuelSupply table is then used to assign these fuel formulations to a month (monthGroupID) and year (fuelYearID) for each fuel region (fuelRegionID), as discussed in Section 4. In the cases where a given fuel region contains more than one fuel of a given fuel subtype (e.g., a fuel region containing both an E10 and an E15 fuel), a value for the fraction of the fuel sold with those properties (marketShare) can be assigned to each of fuels. For more information regarding the specific design and properties of these tables in MOVES201X, please refer to the MOVES201X Module Reference.[9]

5.2 Diesel and CNG

For diesel and compressed natural gas (CNG), we do not use compliance data as the source of the fuel properties. The sulfur contents for diesel (including biodiesel) across all fuel regions are shown in Table 8. Starting in 2006, we assumed that refineries are producing diesel fuel at the maximum 15 ppm sulfur level required by the ULSD regulations.[13]

Table 8 Default Diesel Sulfur Content in MOVES by Calendar Year across All Fuel Regions

Year	Sulfur level, ppm
1990	1000
1999-2005	130
2006-2050	15

For compressed natural gas, we assumed that CNG used in onroad fuels has a sulfur content of 7.6 ppm based on a CNG transit bus study documented in the MOVES fuel effects report.**Error! Bookmark not defined.**

The density, energy and carbon content of the fuels in MOVES are not based on fuel compliance data; these are based on aggregate values that are constant across fuel types and fuel subtypes (see Table 10 below).

[g] The CetaneIndex and PAHContent fields in the fuelFormulation table are currently unused and are populated with NULL values.

The fuel density and the energy content values are stored in the FuelType and FuelSubType tables in MOVES, respectively. Fuel density is classified according to the more general fuel types, and energy content varies according to fuel subtype. Because MOVES reports energy content by fuelsubtype, rather than fueltype, the energy content for each fueltype can be calculated using the energy content of each fuel subtype using the respective fuel subtype market share stored in the MOVES fuelsupply table.

MOVES does not store carbon dioxide emission rates in the emission rate tables (e.g. CO_2/mile or CO_2/hour operation), but calculates carbon dioxide emissions from total energy consumption as shown in Equation 3.

$$CO_2 = Total\ Energy\ Consumed \times Carbon\ Content \times Oxidation\ Fraction \times \left(\frac{44}{12}\right) \quad \textbf{Equation 3}$$

Carbon content is expressed in units of grams of carbon/KJ of energy consumed. Oxidation fraction is the fraction of carbon that is oxidized to form CO_2 in the atmosphere. A small mass percentage of fuel is emitted as carbon monoxide, organic gases and organic carbon. Currently, MOVES assumes an oxidation fraction of 1 for all the hydrocarbon-based fuels. The value (44/12) is the molecular mass of CO_2 divided by the atomic mass of carbon.

The carbon content and oxidation fractions used to calculate CO_2 emissions are provided in Table 9. The carbon content values used currently in MOVES were originally developed for MOVES2004 based on values derived from the life-cycle model GREET.[14]

Table 9 Carbon Content, Oxidation Fraction and Energy Content by Fuel Subtype in MOVES201X

fuelSubtypeID	fuelTypeID	Fuel Subtype	Carbon Content (g/KJ)	Oxidation Fraction
10	1	Conventional Gasoline	0.0196	1
11	1	Reformulated Gasoline (RFG)	0.0196	1
12	1	Gasohol (E10)	0.0196	1
13	1	Gasohol (E8)	0.0196	1
14	1	Gasohol (E5)	0.0196	1
15	1	Gasohol (E15)	0.0196	1
20	2	Conventional Diesel Fuel	0.0202	1
21	2	Biodiesel	0.0201	1
22	2	Fischer-Tropsch Diesel (FTD100)	0.0207	1
30	3	Compressed Natural Gas (CNG)	0.0161	1
40	4	Liquefied Petroleum Gas (LPG)	0.0161	1
50	5	Ethanol	0.0194	1
51	5	Ethanol (E85)	0.0194	1
52	5	Ethanol (E70)	0.0194	1
18	1	Ethanol (E20)	0.0194	1
90	9	Electricity	0	0

Table 10 Fuel Density and Energy Content by Fuel Type in MOVES201X

fuelTypeID	fuelSubtypeID	fuelSubtypeDesc	Fuel Density (g/gallons)	Energy Content (KJ/g)
1	10	Conventional Gasoline	2,839	43.488
1	11	Reformulated Gasoline (RFG)	2,839	42.358
1	12	Gasohol (E10)	2,839	41.762
1	13	Gasohol (E8)	2,839	42.1
1	14	Gasohol (E5)	2,839	42.605
1	15	Gasohol (E15)	2,839	40.92
1	18	Ethanol (E20)	2,839	40.077
2	20	Conventional Diesel Fuel	3,167	43.717
2	21	Biodiesel	3,167	43.061
2	22	Fischer-Tropsch Diesel (FTD100)	3,167	43.247
3	30	Compressed Natural Gas (CNG)	NULL	48.632
4	40	Liquefied Petroleum Gas (LPG)	1,923	46.607
5	50	Ethanol	2,944	26.592
5	51	Ethanol (E85)	2,944	29.12
5	52	Ethanol (E70)	2,944	31.649
9	90	Electricity	NULL	NULL

6 Renewable Fuels Market Share and Usage

Historically, the Annual Energy Outlook report (AEO) generated by the U.S. Energy Information Administration (EIA) has provided the basis for the volumes of biofuels (ethanol and biodiesel) used in the MOVES fuel supplies.[1,2] The AEO report provides year-by-year projections for biofuel energy consumption for gasoline blends (E0-E15), flexible-fuel vehicle (FFV) blends (E70-E85), and biodiesel blends; currently through the year 2050. These projections are used in conjunction with the overall fuel consumption numbers projected by the MOVES model to estimate the market shares of each of these biofuel types for use in the MOVES default fuel supplies.

In the MOVES201X update, we have removed E15 market share projections from the default fuel supply. Analyses for recent regulations, including the 2016 Renewable Fuel Annual Standards[15], have shown that no significant national penetration of gasoline blends above E10 have occurred nationally. Moreover, there is too much uncertainty associated with the movement of fuel through the fuel distribution system to predict regional variation in low penetration E15 levels for specific geographic areas beyond 2016. Individual areas with E15 penetration for years 2016+ should consult the MOVES201X Technical Guidance for information on developing appropriate MOVES inputs.

Flexible fuel vehicle (FFV) market share (the fraction of FFVs sold in the total fleet) and usage fraction (the fraction that FFVs are filled on high-ethanol blends vs. gasoline blends) for MOVES201X are estimated using the vehicle population and energy consumption by fuel type from AEO2017. In MOVES201X, FFV market share for each source type and model year is stored in the stmyFraction column in the SampleVehiclePopulation table.[16] Users may override these market shares using the AVFT table. The FFV usage fraction is contained in the FuelUsageFraction table. The values for these parameters are listed in Table 11 and Table 12 below.

Table 11 FFV Market Shares Used in MOVES201X

Model Year	FFV Market Share (Average)	FFV Market Share (Sourcetype 21)	FFV Market Share (Sourcetype 31)
Pre-1999	0.0		
1999	0.025		
2000	0.034		
2001	0.033		
2002	0.047		
2003	0.049		
2004	0.038		
2005	0.042		
2006	0.038		
2007	0.071		

Model Year	FFV Market Share (Average)	FFV Market Share (Sourcetype 21)	FFV Market Share (Sourcetype 31)
2008	0.076		
2009	0.076		
2010	0.090	0.033	0.151
2011	0.139	0.063	0.225
2012	0.118	0.045	0.203
2013	0.123	0.046	0.209
2014	0.122	0.046	0.204
2015	0.124	0.046	0.192
2016	0.121	0.046	0.190
2017	0.120	0.046	0.190
2018	0.120	0.046	0.189
2019	0.119	0.046	0.190
2020	0.119	0.046	0.189
2021	0.118	0.046	0.189
2022	0.118	0.045	0.190
2023	0.118	0.045	0.190
2024	0.118	0.045	0.190
2025	0.117	0.045	0.190
2026	0.117	0.045	0.190
2027	0.116	0.045	0.190
2028	0.116	0.044	0.190
2029	0.115	0.044	0.190
2030	0.115	0.044	0.190
2031	0.115	0.044	0.190
2032	0.114	0.044	0.190
2033	0.114	0.044	0.190
2034	0.113	0.044	0.190
2035	0.113	0.045	0.190
2036	0.113	0.045	0.191
2037	0.112	0.045	0.191
2038	0.112	0.045	0.191
2039	0.111	0.045	0.191
2040+	0.111	0.045	0.191

Table 12 FFV Fuel Usage Fraction in MOVES201X

Year	FFV Fuel Usage Fraction
1990-2009	0.000
2010	0.001
2011	0.005
2012	0.022
2013	0.035
2014	0.037
2015	0.042
2016	0.041
2017	0.023
2018	0.022
2019	0.026
2020	0.028
2021	0.035
2022	0.058
2023	0.071
2024	0.088
2025	0.113
2026	0.134
2027	0.151
2028	0.165
2029	0.175
2030	0.183
2031	0.200
2032	0.204
2033	0.216
2034	0.223
2035	0.231
2036	0.242
2037	0.250
2038	0.255
2039	0.270
2040+	0.277

For diesel and biodiesel, we assume that conventional diesel constitutes 100 percent of the diesel market share in all fuel regions for 1990 through 2013 calendar years. In 2014 and all later years, we assume that biodiesel (fuelSubtypeID 21) has 100 percent of the diesel market share. The

MOVES fuelFormulation table contain biodiesel blends with 3.4, 5, and 20 percent biodiesel (as well as a conventional B0 diesel blend), which a MOVES user can specify in their fuel supply for a county. However, for the default fuel supply, we assume all biodiesel is B5 (5 percent biodiesel) in all fuel regions, based on national biodiesel penetration volumes, and a lack of locality information for blends higher than B5.

7 Nonroad Fuel Supply

In MOVES201X, the nonroad gasoline fuel supply is consistent with the onroad fuel supply, with exceptions made for nonroad fuel regulations. Specifically, ethanol blends greater than 10 volume percent are not permitted to be used in nonroad gasoline engines.[17] To calculate the nonroad fuel supply, we replaced the onroad marketshare of ethanol blends above E10 (E15, E85) with E10 use, by using the fuel wizard to convert the E15 fuel to E10. Additionally, the spatial allocation of the nonroad fuel supply (gasoline, diesel, CNG, and LPG) is based on was changed from county to fuel region, consistent with the onroad fuel supply.

In the nonroad fuel supply, there are two types of diesel: nonroad diesel (fuelTypeID 23), and marine diesel (fuelTypeID 24). From a MOVES perspective, the only difference in the fuel properties between nonroad diesel and marine diesel is sulfur content. The diesel sulfur content for these fuels used in MOVES is shown in Table 13 below. The sulfur contents for nonroad and marine diesel were set to be consistent with the sulfur levels required by regulation and as modelled in NONROAD2008 (See Table 2 of the referenced document).[18]

In MOVES, the CNG and LPG sulfur levels in nonroad are set at 7.6 ppm for all years, consistent with the onroad CNG sulfur level as discussed in Section 5.

Table 13 Nonroad Diesel Sulfur Content in MOVES201X

	MOVES201X	
Year	**Nonroad**	**Marine**
1999 and earlier	2,284	2,640
2000	2,284	2,640
2001	2,284	2,635
2002	2,284	2,637
2003	2,284	2,637
2004	2,284	2,637
2005	2,284	2,637
2006	2,242	2,588
2007	1,139	1,332
2008	351	435
2009	351	435
2010	165	319
2011	32	236
2012	32	124
2013	32	44
2014	20	52
2015	11	56
2016	11	56
2017	11	56
2018+	11	55

8 Fuel Wizard

To facilitate the analysis of potential fuel control programs for state or local areas, MOVES includes a tool designed to more easily create gasoline-based fuels that are not represented by the default fuel supply. Changes to fuel properties do not happen independently; when refineries change a single property such as sulfur level or RVP, other fuel properties change as well, such as aromatics or the distillation properties (T50, T90, etc). The Fuel Wizard enables the end users to take advantage of the refinery modeling done by EPA as part of the Tier 3 Rulemaking[6], capturing these secondary fuel property changes in a way that does not require significant user effort outside of the MOVES model. This allows for the full impact of proposed fuel changes (as part of state or local programs) to be taken into account, including the associated emission effects of non-regulated fuel property changes.

The adjustment factors used in the Fuel Wizard are the same as those used in creating the default fuel supply (see Table 4, Table 5, and Table 6). The Fuel Wizard applies adjustment factors for the three gasoline properties we believe are the most commonly analyzed for state and local programs: ethanol, sulfur, and RVP. The Fuel Wizard is capable of creating fuels with sulfur from 5 ppm to 80 ppm, RVP from 5 psi to 14 psi, and ethanol variations between E0 – E15. We do not recommend the use of the Fuel Wizard adjustment factors for ethanol levels greater than E15 because any results above E15 are extrapolated, due to constraints in the EPA refinery modeling and because the fuel effects model in MOVES is not capable of modeling emissions on 'mid-level' ethanol blends (blends between E15 and E70).

The Fuel Wizard is used in conjunction with the county data manager in the MOVES graphical user interface (GUI). Guidance on when users should use the Fuel Wizard is provided in our technical guidance.[19] After selecting the fuel listed in the default database that most closely matches the fuel to be analyzed, the end user then invokes the Fuel Wizard to complete the desired changes in fuel properties to the selected fuel. Please note that if multiple fuel property changes are desired (i.e., a change in both sulfur and RVP level), it is possible that some secondary fuel properties may be affected by multiple adjustment factors. Therefore, it is suggested that users change properties in order of least to most significant for the desired analysis.

In MOVES2014, a bug was discovered that would cause incorrect calculations when applying Fuel Wizard correction factors in certain cases. The description of the scenarios that are affected by this bug and the workaround are documented in the MOVES2014a User Interface Reference Manual.[20] However, this patch still relied on users to apply correction factors in the correct order (manually) to achieve an appropriate result. A permanent fix to this bug in MOVES201X required modification of the fuel supply database structure such that the proper order of correction factors can be applied algorithmically based on whether an area falls under a local fuel policy allowing (or disallowing) a 1-psi increase in RVP with the presence of ethanol. This additional information is now contained as part of the regionCounty table, under the fuel waiver parameter (Note to the peer-reviewer – the new algorithm is in the process of being developed and is subject to change).

As new refinery modeling information is generated and analyzed we hope to expand the functionality of the Fuel Wizard to incorporate a wider selection of properties that can be adjusted, as well as capture more complex fuel property interactions.

Appendix A. Summary of EPA Compliance Batch Data for Years 1997-2015

Table A-1 Average Summer Gasoline Properties for All US Gasoline (Except California)

Year	Volume	Oxygen	API Gravity	Ethanol	MTBE	TAME	Sulfur	Aromatics	Olefins	Benzene	RVP	E200	E300	T50	T90
	Million Gallons	Wt%		Vol%	Vol%	Vol%	ppm	Vol%	Vol%	Vol%	Psi	Vol%	Vol%	F	F
1990*	–	0	57.4	–	–	–	339	32.0	13	1.53	8.7	–	–	218.0	330.0
1997	51,179	0.73	58.2	0.31	2.97	0.24	321.6	26.1	12.5	1.02	8.42	46.2	81.1	209.5	336.7
1998	51,823	1.01	58.1	0.70	3.63	0.37	279.4	26.2	11.4	1.02	8.15	45.8	81.3	210.0	333.9
1999	52,091	1.07	58.2	0.90	3.51	0.31	282.9	26.2	11.7	1.04	8.14	46.2	81.5	209.1	333.6
2000	51,326	1.06	58.0	0.92	3.51	0.42	270.6	26.2	11.5	1.01	7.89	45.8	81.7	210.1	333.3
2001	52,238	1.03	57.8	0.83	3.58	0.44	259.1	26.2	12.5	1.03	7.89	45.8	81.9	210.6	331.7
2002	54,647	1.10	57.9	1.02	3.56	0.45	252.4	26.1	11.8	0.97	7.90	45.6	81.6	211.5	333.1
2003	56,954	1.17	57.6	1.10	3.79	0.37	256.9	26.0	11.8	1.02	7.96	45.8	81.6	210.8	333.9
2004	57,256	1.36	58.1	1.90	3.49	0.25	108.6	26.0	11.2	1.01	7.95	45.9	81.4	210.7	334.3
2005	54,476	1.33	58.4	2.07	3.00	0.26	97.3	26.0	12.0	1.07	7.95	46.4	82.3	208.8	330.4
2006	59,777	0.99	57.9	2.70	0.06	<0.01	47.0	25.0	10.5	1.00	7.97	45.3	82.6	–	–
2007	57,938	1.20	58.2	3.31	0.01	<0.01	38.6	24.7	10.6	1.01	8.07	46.1	82.5	–	–
2008	52,958	1.97	59.1	5.50	<0.01	<0.01	31.4	22.9	10.1	0.99	8.22	49.2	85.2	–	–
2009	53,808	2.57	58.5	7.19	<0.01	<0.01	33.5	22.8	10.3	0.94	8.38	49.7	83.4	–	–
2010	53,848	3.10	58.8	8.73	<0.01	<0.01	32.0	22.1	9.9	0.90	8.51	51.1	84.2	–	–
2011	54,535	3.10	59.1	8.81	<0.01	<0.01	29.6	21.1	10.0	0.71	8.60	52.1	85.0	–	–
2012	55,726	3.22	59.4	9.12	<0.01	<0.01	29.6	20.4	9.9	0.62	8.71	52.5	85.3	–	–
2013	54,451	3.31	59.6	9.35	<0.01	<0.01	27.4	20.2	9.7	0.60	8.71	53.1	85.9	–	–
2014	55,763	3.33	59.8	9.38	<0.01	<0.01	24.8	19.7	9.6	0.59	8.71	53.1	85.9	–	–
2015	57,384	3.40	62.2	9.51	<0.01	<0.01	23.5	20.2	9.4	0.59	8.62	52.1	85.6	–	–

Table A-2 Average Winter Gasoline Properties for All US Gasoline (Except California)

Year	Volume	Oxygen	API Gravity	Ethanol	MTBE	TAME	Sulfur	Aromatics	Olefins	Benzene	RVP	E200	E300	T50	T90
	Million Gallons	Wt%		Vol%	Vol%	Vol%	ppm	Vol%	Vol%	Vol%	Psi	Vol%	Vol%	F	F
1990*	–	0	57.4	–	–	–	338.0	26.4	13.0	1.64	11.5	–	–	200.0	333.0
1997	56,041	0.72	61.6	0.31	2.81	0.21	304.5	23.5	12.0	1.01	12.1	52.0	83.7	194.2	326.6
1998	61,127	1.09	61.6	0.90	3.67	0.35	267.0	23.5	11.1	0.98	12.2	51.6	83.7	195.2	325.8
1999	62,685	1.08	61.5	1.04	3.40	0.28	284.5	23.6	11.4	0.98	12.2	51.5	83.5	195.8	327.5
2000	64,248	1.08	61.6	1.20	3.08	0.30	269.9	23.4	12.0	0.97	12.1	51.9	84.1	195.0	323.4
2001	64,915	1.10	61.1	1.23	3.18	0.32	268.2	23.9	12.5	1.02	12.0	51.4	83.9	197.7	324.8
2002	66,155	1.07	61.3	1.23	3.03	0.35	265.2	23.6	11.6	0.96	12.0	51.6	83.8	196.9	325.7
2003	64,663	1.17	61.1	1.53	3.11	0.23	232.3	23.5	11.4	0.98	12.2	51.8	83.5	195.7	327.7
2004	64,910	1.42	61.9	2.14	3.23	0.23	115.0	23.1	11.3	0.96	12.2	52.2	83.8	194.9	326.1
2005	65,190	1.42	61.9	2.37	2.80	0.21	92.7	23.3	11.5	1.02	12.0	52.3	84.4	194.8	323.9
2006	68,602	1.12	61.6	2.60	1.18	0.06	47.8	21.9	10.5	0.97	12.0	52.4	84.6	–	–
2007	65,081	1.32	61.9	3.59	0.02	<0.01	37.0	21.7	10.5	0.96	12.1	52.7	84.9	–	–
2008	61,486	2.06	62.2	5.69	<0.01	<0.01	34.2	20.6	10.1	0.97	12.2	54.5	86.3	–	–
2009	62,110	2.67	61.8	7.38	<0.01	<0.01	31.4	20.2	9.7	0.95	12.3	55.4	86.0	–	–
2010	62,992	3.15	61.8	8.80	<0.01	<0.01	31.9	19.7	9.7	0.85	12.3	56.2	86.2	–	–
2011	66,683	3.15	62.1	8.86	<0.01	<0.01	29.4	18.7	9.5	0.68	12.3	57.1	87.0	–	–
2012	64,028	3.26	62.5	9.16	<0.01	<0.01	28.5	18.3	9.1	0.62	12.5	57.7	87.2	–	–
2013	65,303	3.35	62.7	9.35	<0.01	<0.01	26.6	17.8	9.1	0.57	12.6	58.0	87.8	–	–
2014	67,298	3.35	62.9	9.36	<0.01	<0.01	25.2	17.5	8.9	0.57	12.8	58.0	87.9	–	–
2015	68,140	3.46	64.9	9.52	<0.01	<0.01	23.0	17.8	8.6	0.57	12.7	57.5	87.6	–	–

Table A-3 Average Annual Gasoline Properties for All US Gasoline (Except California)

Year	Volume	Oxygen	API Gravity	Ethanol	MTBE	TAME	Sulfur	Aromatics	Olefins	Benzene	RVP	E200	E300	T50	T90
	Million Gallons	Wt%		Vol%	Vol%	Vol%	ppm	Vol%	Vol%	Vol%	Psi	Vol%	Vol%	F	F
1997	107,220	0.72	60.0	0.31	2.89	0.22	312.6	24.7	12.2	1.01	10.34	49.3	82.5	201.5	331.4
1998	112,950	1.05	60.0	0.80	3.65	0.36	272.7	24.8	11.2	1.00	10.35	49.0	82.6	202.0	329.5
1999	114,776	1.08	60.0	0.97	3.45	0.29	283.8	24.8	11.5	1.00	10.33	49.1	82.6	201.9	330.2
2000	115,574	1.07	60.0	1.07	3.27	0.35	270.2	24.6	11.7	0.99	10.23	49.2	83.0	201.7	327.8
2001	117,153	1.07	59.6	1.05	3.36	0.37	264.1	24.9	12.5	1.02	10.17	48.9	83.0	203.5	327.9
2002	120,802	1.08	59.8	1.14	3.27	0.39	259.4	24.7	11.7	0.97	10.16	48.9	82.8	203.5	329.1
2003	121,617	1.17	59.4	1.33	3.43	0.30	243.8	24.7	11.6	1.00	10.20	49.0	82.6	202.8	330.6
2004	122,166	1.39	60.1	2.02	3.35	0.24	112.0	24.5	11.3	0.98	10.21	49.3	82.7	202.3	330.0
2005	119,666	1.38	60.3	2.23	2.89	0.23	94.8	24.5	11.7	1.04	10.18	49.7	83.4	201.2	326.9
2006	128,379	1.06	59.9	2.64	0.66	<0.01	49.2	24.7	11.1	1.04	10.15	49.1	83.7	–	–
2007	123,019	1.27	60.2	3.44	0.02	<0.01	39.9	24.4	11.2	1.04	10.20	49.6	83.8	–	–
2008	114,444	2.02	60.8	5.54	<0.01	<0.01	34.2	22.5	10.5	1.02	10.33	52.0	85.8	–	–
2009	115,918	2.62	60.3	7.20	<0.01	<0.01	33.3	22.0	10.3	0.97	10.47	52.7	84.8	–	–
2010	116,840	3.13	60.4	8.65	<0.01	<0.01	32.4	21.2	10.0	0.89	10.54	53.8	85.3	–	–
2011	121,218	3.13	60.7	8.72	<0.01	<0.01	30.0	20.2	9.8	0.70	10.64	54.7	86.0	–	–
2012	119,754	3.24	61.0	9.01	<0.01	<0.01	29.4	19.6	9.6	0.63	10.73	55.2	86.3	–	–
2013	119,754	3.33	61.3	9.21	<0.01	<0.01	27.2	19.1	9.5	0.59	10.82	55.7	86.9	–	–
2014	123,061	3.34	61.4	9.23	<0.01	<0.01	25.3	18.8	9.3	0.59	10.95	55.6	87.0	–	–
2015	125,524	3.43	63.7	9.38	<0.01	<0.01	23.4	19.0	9.0	0.58	10.83	55.0	86.6	–	–

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