Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES2014b

United States Environmental Protection Agency

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United States Environmental Protection Agency

EPA-420-R-18-008
July 2018

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1 Executive Summary

Historically, EPA has used a combination of disparate sources of fuel property data to populate the local fuel quality database tables included in the MOVES model. These data sources, including surveys from the Alliance of Automobile Manufacturers (AAM), state and local point source sampling, and reformulated gasoline (RFG) compliance reports, have always provided a detailed snapshot of fuel qualities for a given local area at a given time. However, in reviewing the results of this approach in the context of our knowledge of national gasoline production and distribution, EPA believes that this approach over-specified the local fuel properties beyond the capabilities of the available data. We have overhauled and simplified the aggregation of fuel survey data for use in the MOVES model, as well as now including the extensive refinery gate batch dataset collected as a part of EPA compliance programs. This has had the effect of reducing the total number of unique fuel property areas from approximately 425 in MOVES2010 and its minor releases[a] (hereafter referred to as MOVES2010) to approximately 45 in MOVES2014, generally representing the geographic distribution of refined products pipelines and taking into account state and local fuel programs. These fuel properties are also now projected to 2050 in MOVES2014 using estimates from the Annual Energy Outlook[b,1,2]) report, and includes E15 and E85 use (a large update from MOVES2010, which held fuels constant beyond 2012 and did not contain E15 fuel supplies). In doing so, we hope to have 1) clarified the source of the fuel properties 2) better represented the actual in-use fuel properties and 3) better represented the actual variation in fuel properties across different regions in the U.S.

Additionally, we have included the fuel wizard tool in MOVES2014 that allows users to adjust local fuel properties using EPA refinery modeling based on 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.

2 Introduction

This document describes the background and methodology behind the changes and updates to the fuel supply components of MOVES2014 and its minor releases, MOVES2014a and MOVES2014b.

Section 3 provides an overview of the fuel supply in MOVES2010 and describes our rationale for significantly changing the data and structure of the fuel supply in MOVES2014. For more information on the fuel supply included in the MOVES2010 model, please see the MOVES2009 Fuel Effects report[4].

Section 4 defines the large geographical areas used in the new MOVES2014 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 E15 and E85), into

[a] Including MOVES2010a and MOVES2010b

[b] MOVES2014 used the AEO2014 Early Release[1]. MOVES2014a used the AEO2014 Final Release[2].

future years. Section 7 describes the development of the fuel supply used in MOVES2014 specifically for 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.

We updated both the fuel supply and fuel wizard in MOVES2014a from MOVES2014. The specifics and the emission impacts of these changes are discussed in Sections 6, 7, and 8. The report refers to MOVES2014 for the general structure and changes made to MOVES2014. We refer to MOVES2014a to discuss changes that were made between MOVES2014a and MOVES2014.

3 Background

The fuel supply in MOVES2010 included extensive fuel property data taken from many sources, including AAM fuel surveys, state and local point source sampling, and EPA collected reformulated gasoline compliance data. However, while these data may provide accurate fuel property information in a specific location and at a specific point in time, they may not have provided a true reflection for an area over time, given the limitations in the data and how it was collected. It resulted in significant differences in fuel properties between even neighboring counties, even though they would have received fuel from the same fuel distributors. These differences were left largely unresolved in the default fuel database included in MOVES2010, leaving the model with a patchwork of many disparate regions with large variations in fuel properties that generally did not follow geographic regions, pipeline and terminal locations, or in some cases local fuel control areas. See Figure 1 for an example of the large number of differing fuel property areas included in the fuel database for MOVES2010.

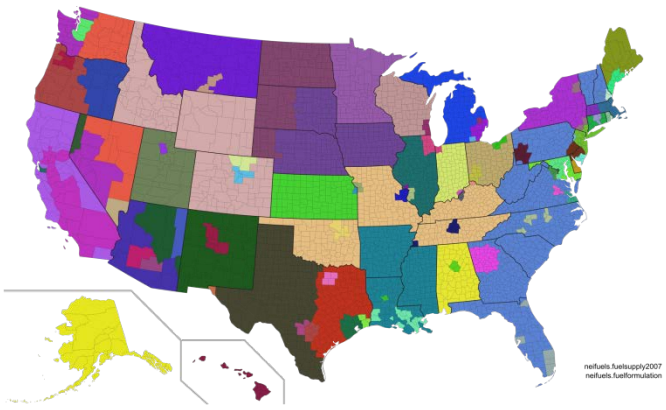

Figure 1 - Disparate fuel property areas in the MOVES2010 model

Note: Each color represents a difference in any single fuel property for a given county. This example is taken from the MOVES2010b fuel supply for calendar year 2007.

We believe that an improved method should be used to generate these fuel supply areas, as the MOVES2010 method may exaggerate emission inventory differences among neighboring counties in different fuel supply areas, and therefore, we sought a new technique to refine the generation of the default fuel database for MOVES2014.

The new technique relies more heavily on our nationwide refinery gate compliance data set (EPA collects electronic records of refinery fuel property data as it leaves the facility, for compliance purposes), and less on 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) that were not being used in the previous versions of MOVES. This data was used by EPA for the Tier 3 rulemaking analysis.[5] This dataset includes approximately thirty thousand entries per year (each entry containing batch-specific properties), with EPA using the years 2007, 2009, and 2011 for the MOVES2014 analysis.

After the initial aggregation of this compliance batch data, it became apparent that our previous method of basing large geographic areas on a small number of point-source samples was inadequate. Batch to batch variation was much larger than we had assumed in the previous modeling attempts. Figure 2 provides an example of the batch to batch variation that occurs for E200 (the percentage of fuel that evaporates at 200 ℉). 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 MOVES2014 Fuel Effects report[6]).

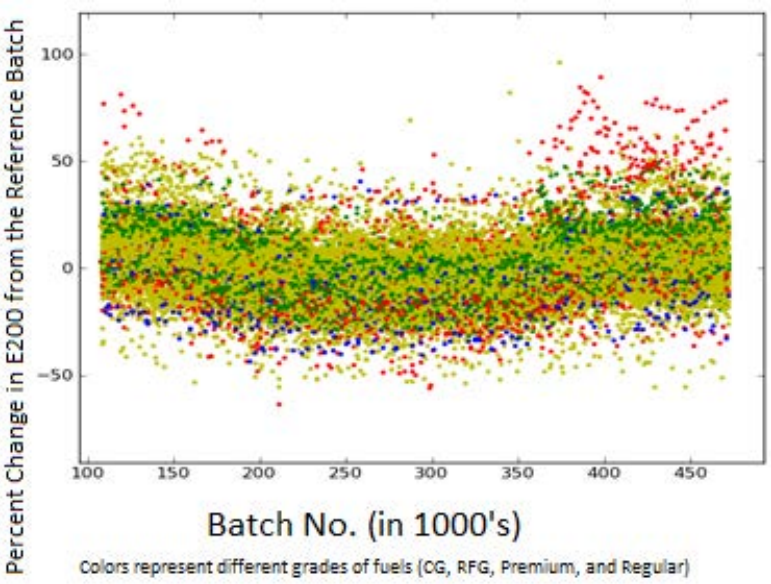

Figure 2 – Example of fuel quality variation (E200) from EPA compliance data

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, a new aggregation methodology was developed 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 AAM and other sources, as well as applying the latest refinery

modeling developed as part of the Tier 3 rulemaking process. With this new methodology, we believe that the fuels contained in the default MOVES2014 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 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 as a part of defining the new regional fuel areas. Within these broad fuel regions, we further identified areas requiring additional unique fuel qualities, due to federal, state, or local fuel quality standards.

Figure 3 - An example of petroleum product pipelines in the continental United States[8]

Although an area has not been specifically defined for the historical Geographic Phase-in Area (GPA) as was done for the MOVES2010a model, we have created a fuel region including the Rocky Mountain area closely related to this area. Table 1 identifies and briefly describes each region as used in the MOVES2014 default fuel supply database. Additionally, please see Figure 4 for a graphical representation of these new fuel regions, including areas adjusted from the large

fuel region aggregates to account for state or local fuel control programs. Comparing Figure 4 to Figure 1 helps illustrate the major changes from the versions of the MOVES2010a model to MOVES2014.

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	**CA/NV/AR/All Others**	California[c], 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

[c] Currently, Base Region 6 does not include any market share in California in MOVES2014.

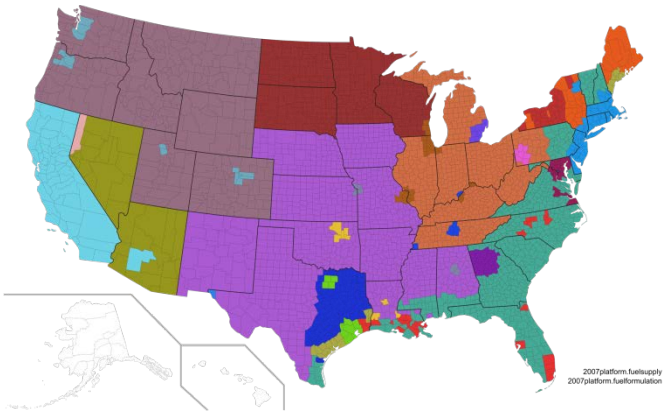

Figure 4 - Fuel Regions in the MOVES2014 model

The MOVES2014 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 [*regionID*] for a given year [*fuelYearID*], including regions with state or local fuel control programs.[d] The regionCounty also has an identifier [*regionCodeID*] which identifies onroad or nonroad use, 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 MOVES2014, please refer to the MOVES Module Reference[9].

The *regionID* 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:

regionID: AABBCCDDXX

where: AA = base region ID

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

[d] For the October release of MOVES2014, we updated the county to fuel region assignments based on updates to local fuel programs. We changed the fuel region assignment for the following North Carolina counties (Davidson, Davie, Durham, Forsyth, Granville, and Guilford) from the East RVP control area (RegionID 178000000) to the East Coast region with no local fuel control programs (RegionID 100000000).

The contents of the regionID 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,e] 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, each fuel region is defined on the presence of an RVP waiver.

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

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

Table 2. RegionID Table in MOVES2014

regionID	AA, Base Region ID#	Base Region Name	BB, Maximum summer RVP (psi) or 00 for ASTM	CC, E10 RVP Waiver (00=1 psi waiver, 01=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, MOVES2014 has 24 fuel regions, when combining the base fuel areas with the state and local fuel control programs. We may consider additional fuel regions in the future based on fuels data and recommendations from users.[13] 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 this the default fuel database in MOVES2014, we have chosen to keep the fuel regions consistent (a snapshot in the year 2013) 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

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 compliance process. This data is provided to us 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 MOVES2014, we chose to use 2007, 2009, and 2011 as the 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 the specific type of fuel created (e.g., CG, BOB, RFG). These reported properties form the basis for the fuel properties used in the regional fuel methodology, and are eventually aggregated into 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:

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 (i.e., 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). Finally, we separated differing types of fuel batches for further processing (i.e., CG and pre-blended fuels can be included in the dataset without adjustment, BOB fuels must be adjusted to account for oxygenates added downstream from the refinery gate). After these processing steps, we were left with a set of data containing between twenty and thirty-five thousand usable points of batch properties (depending on year), with no fuel region being represented by less than one thousand batches.

$$T_{50} = 2.0408163 \times (147.91 - E_{200})$$ **Equation 1. T50 Correlations to E200**

$$T_{90} = 4.5454 \times (155.47 - E_{300})$$ **Equation 2. T90 Correlations to E300**

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 transitionary '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).

In addition to the EPA compliance data, we also included point source downstream fuel sampling data measured by the AAM[11]. While this data cannot represent fuel properties for a region on its own (as explained in Section 3), it serves as an important validation to adjustments made to compliance data to account for BOB fuels, as well as aggregate results. 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 the given fuel region.

As part of the Tier 3 rulemaking (which includes reductions in fuel sulfur content), adjustments to secondary fuel properties affected by changes in sulfur, RVP, and ethanol level were generated using refinery modeling tools.[5] EPA understands that fuel property changes cannot happen independently, and has made an effort to capture these interactive effects in the MOVES2014 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)										
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						

Gasoline fuel compliance data suggests that the vast majority of fuel batches (>80 percent in the 2011 database) produced by refiners are produced as a match blendstock (CBOB/RBOB) for downstream ethanol blending. Therefore, for calendar years beyond 2011, when making adjustments to include the addition of ethanol (as E10 or E15 fuel), we did not include the additional dilution effects on sulfur or other fuel properties occurring from this blending beyond those required to meet federal, state, or local limits. Table 7 shows the gasoline sulfur levels used in MOVES2014 for 2011 and later years. 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 2011, we used the batch fuel data as the source of the fuel sulfur content. For these years, the sulfur level of conventional gasoline and E10 exceeds 30 ppm, and varies between base fuel regions.

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
2011-2016	30	9	8
2017-2050	10		

Unfortunately, even though MOVES2014 includes the years 1990 and 1999-2050, batch fuel compliance data was not available for use as part of this analysis for years prior to 2006 or after 2011 (records before this period exist in non-electronic form, for more information see the 2005 Fuels Trends report[12]). For the years 1990, 1999, and 2000-2005, we used county specific fuel data contained in MOVES2010 as a surrogate for aggregation. 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 occurring by VMT in those counties. For fuel property data after 2011, we assumed no change to current fuel properties until affected by statutory regulations, such as Tier 3. As such, the database will contain major fuel property changes in 2017, and then remain constant afterwards. This excludes the volumes of renewables included in the fuel supply, which vary by year, and are described in more detail in Section 6. Of course, in reality, there will be changes to fuel property data due to market shifts in future years 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 be including this data in future versions of the MOVES model.

As part of the update to MOVES2014, we have included a new fuel effects model based on the EPAct/V2/E-89 (EPAct) gasoline fuel effects study.[6] The fuel effects model contains adjustments to gasoline vehicle emission rates based on specific fuel properties such as ethanol, aromatics, RVP, and distillation properties as well as interactions between these properties and replaces the Complex Model[4] for vehicles model years 2001 and newer. For more information on the specifics of this new fuel effects model, please refer to the MOVES2014 Fuel Effects report.[6]

We are aware that for some regions, there may still be MTBE in-use post-2001, a fuel property that cannot be properly modeled using the EPAct fuel effects model. In MOVES2014, regions using MTBE fuel have been replaced with ethanol (E10) fuel in order to provide an approximation of fuel effects in years post-2001. A solution for this limitation in historical MTBE modeling may be explored in future versions of the MOVES model.[13]

In MOVES2014, 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, and now the EPAct Model), including *RVP, sulfurLevel,*

[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 MOVES2014a, all E15 from the California fuel supply was removed to correctly reflect the fuels in California.

ETOHvolume, MTBEvolume, TAMEvolume, aromaticContent, olefinContent, benzeneContent, e200, e300, volToWtPercentOxy[g,14]*, BioDieselEsterVolume, CetaneIndex*[h]*, PAHContent*[h]*, 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 can be assigned to each of fuels [*marketShare*]. For more information regarding the specific design and properties of these tables in MOVES2014, please refer to the MOVES2014 Module Reference.[9]

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 maximum15 ppm sulfur level required by the regulations.[15]

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.[6]

The density, energy and carbon content of the fuels in MOVES2014 are not based on fuel compliance data; these are based on aggregate values that are constant across fuel types and fuel subtypes as documented in the MOVES GHG and energy report.[16,i]

[g] The volToWtPercentOxy values are documented in Table 3-2 of the MOVES Report Speciation of Total Organic Gas and Particulate Matter Emissions from On-road Vehicles in MOVES2014[12]. MOVES2014a currently does not use the volToWtPercentOxy values in the fuelFormulation table, but uses identical hardcoded values. Thus, changing the VolToWtPercentOxy values in the fuelFormulation table will not change the results.

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

[i] In MOVES2014a, we updated the energy content of biodiesel to 43.061 (KJ/g) instead of 41.738 (KJ/g) to reflect B5 energy content, rather than B20.

6 Renewable Fuels Market Share

The Annual Energy Outlook report (AEO) generated by the U.S. Energy Information Administration (EIA) provides the basis for the volumes of biofuels (ethanol and biodiesel) used in the MOVES2014 fuel supplies.[1,2] The AEO report provides year-by-year projections for biofuel energy consumption by fuel type for ethanol-gasoline blends (E0, E10 and E15), flexible-fuel vehicle (FFV) blends (E70-E85), and biodiesel blends; currently through the year 2040. We use these projections in conjunction with the overall fuel consumption numbers projected by the MOVES model to calculate the marketshares of each of these biofuel types for use in the MOVES2014 fuel supplies.

Generally, the AEO reports have only described biofuel energy consumption on a national basis. However, as part of the Tier 3 rulemaking, EIA provided the agency a breakdown, by region, of ethanol marketshares used in their modeling in conjunction with the AEO2013 final report.[17] EPA has continued using this regional breakdown to more accurately identify the differences in ethanol adoption rates between fuel regions. Currently, ethanol is the only biofuel with regional variation reflected in the model. We are aware that state and local programs may also cause significant variation in biodiesel distribution as well, and further updates to the regional penetration of biofuels may be included in future versions of MOVES.

The fuel regions used in the AEO analysis are defined as part of their economic modeling, and are not identical to the fuel regions created for MOVES2014, as explained in the previous section. This necessitated the creation of a mapping scheme for our analysis. Fortunately, the EIA regions are bounded on a state scale and can be easily allocated to county for our purposes.

Although the AEO reports form the basis of vehicle activity forecasts in the MOVES model, vehicle energy use in MOVES2014 is not directly taken from the AEO reports; it is calculated as part of the operation of the model. In order to apply the ethanol and biodiesel data from AEO, it was necessary to reconcile the differences between the energy use found in those reports with the energy use reported by the MOVES model. Using county VMT as a scaling factor, MOVES vehicle energy consumption by fuel type was calculated for each county based on a national MOVES run producing overall energy consumption. Then, by scaling AEO energy use to match that generated by MOVES, we can find an appropriate adjustment factor that correctly applies AEO biofuel volumes to the MOVES fuel supplies. This allows the MOVES model to retain the correct marketshare of alternative fuels found in the AEO, despite having differing total energy use (such that if MOVES were to generate exactly the same energy as AEO, the biofuel volumes would also be identical). The adjustment factor used for estimating MOVES2014a energy consumption is 0.956 of the AEO energy consumption.

After resolving the energy use between MOVES and AEO, we then calculated an additional adjustment factor to the regional maximum E15 penetrations (matching the regional variation reported by EIA in the Tier 3 report discussed above) in order to apply an appropriate E10 to E15 marketshare ratio in the default fuel supply. By using an adjustment factor for E15 penetration, we preserved the relationship between regional penetrations while still applying the correct total volume of ethanol to each county. The adjustment factor used for estimating MOVES2014a E15 penetration is 0.114 of the AEO 2014 projection.

An example illustrating the phase-in of ethanol (both as E10 and E15, as well as FFV fuel) for a specific fuel region can be found in Figure 5 below.

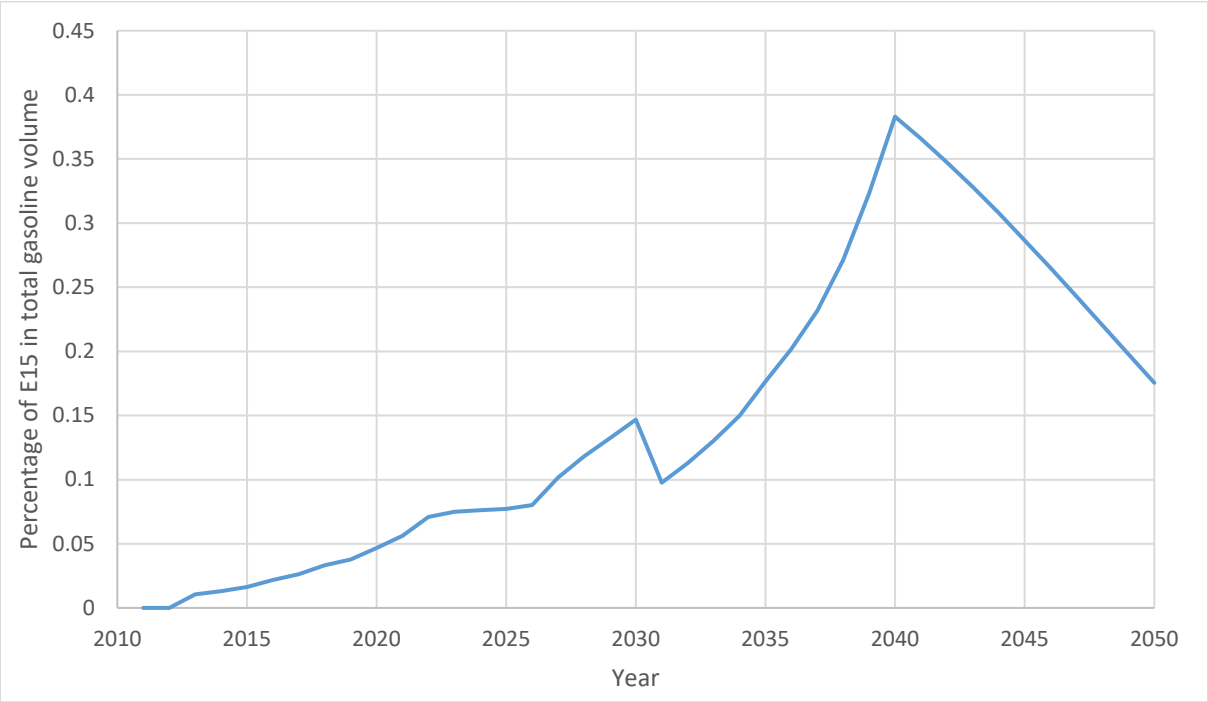

Figure 5 - E15 Phase-in as applied in MOVES2014a for a specific fuel region

In MOVES2014a, we updated the fuel supply to reflect the AEO2014 final release[2], and made it consistent with other changes including: removing E15 from the California fuel region[f] and new fuel region assignments based on updates to local fuel programs[d]. These changes caused the marketshare of E15 and E10 to change for all regions. However, for a typical county, the emissions impact of these changes are minimal, impacting VOC, CO, NOx and PM onroad emissions by less than 1 percent between MOVES2014 and MOVES2014a.[18]

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 marketshare. The MOVES2014 fuelFormulation table contain biodiesel blends with both 3.4, 5, and 20 percent biodiesel, 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.[i]

7 Nonroad Fuel Supply

In MOVES2014, the nonroad fuel supply was based on the fuels used in NMIM 2008, with fuel supply spatially allocated by individual counties.[19]

However, in MOVES2014a, we updated the nonroad gasoline fuel supply to be 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.[20] 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) 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). 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 MOVES2014, MOVES2014a, and MOVES2014b is shown in Table 9 below. The sulfur content was updated in MOVES2014a to be consistent with the sulfur levels used in NONROAD2008 (See Table 2 of the referenced document).[23] Additionally, MOVES2014b corrected nonroad and marine diesel sulfur levels to be consistent with ULSD standards in years 2014 and later.

In MOVES2014, the sulfur level of nonroad CNG and LPG was 16 ppm for all years. However, in MOVES2014a, the CNG and LPG sulfur levels were updated to be 7.6 ppm for all years, consistent with the onroad CNG sulfur level as discussed in Section 5.

Peer review comments of this document noted that marine diesel sulfur levels in MOVES2014a exceeded the regulatory limits of the ULSD program and that nonroad and locomotive diesel sulfur levels were lower than regulatory limits without supporting data for years 2014+.[21] MOVES2014b has corrected these values to be consistent with the ULSD program regulatory levels.

Table 9. Nonroad diesel sulfur content in MOVES2014, MOVES2014a, and MOVES2014b

	MOVES2014		MOVES2014a		MOVES2014b	
Year	Nonroad	Marine	Nonroad	Marine	Nonroad	Marine
1999 and earlier	2284	2640	2284	2640	2284	2640
2000	2284	2637	2284	2640	2284	2640
2001	2284	2637	2284	2635	2284	2635
2002	2284	2637	2284	2637	2284	2637
2003	2284	2637	2284	2637	2284	2637
2004	2284	2637	2284	2637	2284	2637
2005	2284	2637	2284	2637	2284	2637
2006	2284	2637	2242	2588	2242	2588
2007	351	435	1139	1332	1139	1332
2008	351	435	351	435	351	435
2009	351	435	351	435	351	435
2010	351	435	165	319	165	319
2011	32	124	32	236	32	236
2012	32	124	32	124	32	124
2013	32	124	32	44	32	44
2014	11	55	20	52	15	15
2015	11	55	11	56	15	15
2016	11	55	11	56	15	15
2017	11	55	11	56	15	15
2018+	11	55	11	55	15	15

As expected, there was a significant increase in the marketshare of E10 in the nonroad fuel supply between MOVES2014 and MOVES2014a. For the years 2015-2030, the E10 marketshare increased from 79 percent of the total nonroad gasoline consumption in MOVES2014 to 100 percent of the nonroad gasoline consumption. With the fuel supply change in MOVES2014a, a typical urban county in the years 2015-2030, nonroad emissions were reduced by 1.5 percent-4.4 percent for total hydrocarbon emissions (THC), 2.4 percent-7.6 percent for carbon monoxide (CO) emissions, and increased by 0.4-2.3 percent for NOx emissions. There were negligible changes in PM emissions consistent with small changes in sulfur levels between the two fuel supplies. These changes are consistent with the nonroad fuel effects in MOVES2014, where increasing the gasoline oxygenate level decreases THC and CO, decreases NOx emissions.[22] In MOVES2014, the diesel fuel sulfur impacts nonroad sulfate emissions, which contributes a small percentage of the $PM_{2.5}$ exhaust emissions.[23]

MOVES2014a added the capability to calculate speciated organic emissions, including volatile organic compound (VOC) emissions from nonroad THC emissions. VOC emissions are calculated as a ratio to non-methane hydrocarbon emissions (NMHC) emissions. For gasoline nonroad engines, the VOC/NMHC ratio is a function of the ethanol level as documented in the Nonroad Speciation Report.[24] Thus, changes in the nonroad fuel supply in MOVES2014a also impact the speciated organic gaseous emissions from nonroad gasoline equipment.

8 Fuel Wizard

In order to more easily facilitate the analysis of potential fuel control programs for state or local programs, EPA has created a new tool in MOVES2014a designed to more easily create fuels that are not represented by the default onroad fuel supply. Changes to fuel properties do not happen independently; by changing 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, capturing these secondary fuel property changes in a way that does not require significant 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 subsequent effects of non-regulated fuel property changes on emissions.

The adjustment factors used in the fuel wizard are the same as those used in the creation of the default fuel supply (see Table 4, Table 5, and Table 6). The fuel wizard contains adjustment factors for the three properties we believe are the most commonly analyzed for state and local programs: ethanol, sulfur, and RVP. The fuel wizard is currently capable of creating fuels with ethanol variations between E0 – E15, sulfur from 5 ppm to 80 ppm, and RVP from 5 psi to 14 psi.

As part of the MOVES2014a update from MOVES2014, we corrected the fuel wizard to repair several errors (primarily in the fuel adjustments for RVP and sulfur) that led to erroneous fuel property adjustments.[25,28] These errors only existed in the fuel wizard tool provided for MOVES users, and did not impact the default fuel properties in the MOVES fuelFormulation table.

In MOVES2014a, we also updated the fuel wizard to not allow users to enter ethanol levels greater than 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 MOVES2014 fuel effects model is not capable of modeling '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.[26] After selecting a fuel contained 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 the fuel wizard be used by changing properties in order of least to most significant for the desired analysis.

We have also released a patch to MOVES2014a, the "MOVES2014a November 2016 patch", which included an additional fix to the fuel wizard. The fuel wizard in MOVES2014a correctly calculated the changes in fuel properties when the ethanol volume of a fuel was changed from E0 to E10, or from E10 to E0 for an area with the 1 psi RVP waiver. However, the fuel wizard did not produce correct fuel properties when a user in the 1 psi RVP waiver area changed the ethanol

volume of a fuel from E10 to E15, or from E15 to E10. The November 2016 patch to the fuel wizard corrected this issue.

For areas without the 1 psi waiver, the fuel wizard in MOVES2014a produced inaccurate fuel properties when the ethanol volume of a fuel was changed from E0 to E10, E10 to E0, E10 to E15, and E15 to E10. The step-by-step instructions for avoiding this bug are provided in the User Interface Reference Manual.[27] We plan to fix this bug permanently in the next version of MOVES.

The emissions impacts of the fuel wizard bug in MOVES2014a without the patch is summarized in Table 10.

Table 10. Percent differences in emissions between the correct fuel based on refinery modeling and the incorrect fuel predicted by MOVES2014a fuel wizard for two sample counties in July 2015†

Ethanol Content	Areas with 1 psi RVP wavier				Areas without 1 psi RVP wavier			
	E0 to E10	E10 to E0	E10 to E15	E15 to E10	E0 to E10	E10 to E0	E10 to E15	E15 to E10
NOx	0%	0%	-0.6%	0.5%	0.2%	-0.2%	0.1%	-0.3%
VOC	0%	0%	-3.2%	2.9%	-0.2%	0.4%	2.6%	-3.2%
$PM_{2.5}$	0%	0%	-0.5%	0.5%	-0.3%	0.3%	0.6%	-0.8%
CO	0%	0%	-1.7%	1.9%	0.7%	0%	1.1%	-1.3%

† The results may vary by region, calendar year, and month.

As new refinery modeling information is generated (either as part of agency rulemakings or from external modeling efforts[j,13,28]), we plan on expanding the functionality of the fuel wizard to both incorporate a wider selection of properties that can be adjusted, as well as capture more complex fuel property interactions.

[j] For example, we are evaluating data shared to us on the variable impact of ethanol on T50 provided in the CRC Review of MOVES2014.[13,27]

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