JULY 2019

An Assessment of the Renewable Fuel Standard Using EVA-NEMS

July 17, 2019

ENERGY VENTURES ANALYSIS

Prepared for:

The Fueling American Jobs Coalition

Prepared by:

ENERGY VENTURES ANALYSIS

1901 N. Moore Street
Suite 1200
Arlington, VA 22209-1706

703-276-8900
www.evainc.com

Table of Contents

Figures

Tables

I. Executive Summary

Energy Ventures Analysis (EVA) was retained to review the Renewable Fuel Standard (RFS) in the context of current and potential future policy directions on behalf of the Fueling American Jobs Coalition.

To accomplish this review, EVA took two approaches. In the first approach, EVA used the U.S. Energy Information Administration's (EIA) National Energy Modeling System (referred to a EVA-NEMS in this report) to assess the impacts of continuing the RFS through 2030 in terms of gasoline and diesel prices to consumers, ethanol production and consumption in motor gasoline, corn production and prices, and the composition of vehicle sales. Specifically, what would the impacts be of eliminating the RFS as compared to attempting to push even more corn ethanol into motor fuels, and then contrasting those cases to a third case that generates significant consumer savings and supports biofuels. The second approach is a case study analysis, focusing on the U.S. east coast (referred to as PADD I), that considers the unique position of merchant refineries[1] located primarily on the east coast and how the RFS implicitly favors the integrated refinery model versus the merchant refinery model for the refining industry.

The current RFS was created in 2005[2] and 2007,[3] a period when energy markets in the United States were ramping up imports of petroleum and other liquid fuel to more than 60 percent of total U.S. demand. At the same time, demand for motor fuels was increasing, and U.S. production of crude oil was stagnant or declining.[4] The goals of the RFS include moving the United States toward greater energy independence and security, increasing the development and production of "second generation biofuels," and supporting rural economies by expanding the demand for agricultural products.[5]

Results presented in this report demonstrate that the RFS mandate is no longer relevant as an energy policy. Better ways to advance these policy goals may exist, but the outdated RFS is not one of them. This report demonstrates and describes the failings of the RFS and provides recommendations for amending the existing program.

The high-level findings of this report include the following:

- **Consumers will annually pay more than $8 billion more at the pump in 2025 and 2030 if the RFS were allowed to continue its current trajectory, and the use of biofuels in motor fuels will change very little.**
  - The EVA-NEMs results demonstrate that the RFS increases consumer expenditure on gasoline by $8.7 billion and $8.4 billion in 2025 and 2030, respectively, compared with eliminating the RFS altogether.
  - Eliminating the RFS altogether would decrease the biofuel percentage in motor gasoline by only 0.3 percentage points by 2025, from 10.8 percent to 10.5 percent, which illustrates the difficulties associated with attempting to push additional volumes of ethanol above the 10 percent level.
- **The current RFS does not support U.S. corn growers**
  - The EVA-NEMS results demonstrate that, if the RFS standards were eliminated, U.S. corn-based ethanol and biobutanol production remains at nearly the same levels as in the EIA Reference case.
  - This result occurs because the production cost of ethanol is lower than the cost of motor gasoline blendstocks produced by refineries, creating the economic incentive to blend ethanol even in absence of the mandate.

[1] A merchant refinery is a crude oil refinery that buys and refines crude oil and sells its products to wholesalers rather than directly to consumers.
[2] *Energy Policy Act of 2005* (P.L. 58; Sec. 1501-1516).
[3] *Energy Independence and Security Act of 2007* (P.L. 110-140; EISA, Sect. 201-202).
[4] U.S. Energy Information Administration, *Annual Energy Outlook 2007*, February 2007, pp. 10-11, p. 80, and Table A11 p. 157-158.
[5] E.g., James H. Stock, *Reforming the Renewable Fuel Standard*, February 2018, p. 7. Columbia SIPA Center on Global Energy Policy.

- Even if the RFS were to be pushed even higher, U.S. corn prices and would not appreciably increase.

- **Ethanol consumption under the existing RFS is projected to decrease in the future**
  - The EIA Reference case projects declining motor gasoline consumption from 143 million gallons to 117 million gallons by 2030.
  - As a result, the implied corn ethanol mandate is projected to decrease from 15 million gallons to slightly more than 13 million gallons by 2025.

- **Assuming no increases in the amount of advanced biofuels mandated, significant savings to consumers can be achieved by resetting the RFS to focus on non-ethanol biofuel**
  - Eliminating the implied mandate for corn-based ethanol through an Advanced RFS case would result in consumer savings of $3.7 billion and $5.3 billion in 2025 and 2030, respectively.
  - Removing the reliance on advanced biofuels like biodiesel to support the total mandate (i.e., the de facto conventional biofuels mandate), while allowing for keeping biomass-based diesel mandate at 2018 levels, combine to generate the savings for consumers.
  - U.S. corn production would be largely unchanged in 2025 and 2030.

- **Projected vehicle demand and the associated infrastructure changes do not support significant growth in ethanol consumption through 2030**
  - The EVA-NEMS results demonstrate that the Flexible Fuel Vehicles (FFVs) are a relatively minor share of future new vehicle sales through 2030.
  - Automobile manufacturers have focused development efforts on electric vehicles (EVs) and other vehicle types.
  - The difference between ethanol supply and feasible ethanol demand is a major driver of RFS compliance costs.
  - The United States lacks sufficient infrastructure to readily absorb more ethanol in the fuel supply than is currently being produced.

- **The RFS does not support energy independence or energy security**
  - Under all cases analyzed in this report, the U.S. becomes a net exporter of petroleum and other liquids by 2025.
  - Completely eliminating the RFS would change U.S. net import dependency on petroleum and other liquids by only 1.2 percentage points by 2030, from *negative* 17.6 percent to *negative* 16.4 percent. In other words, the U.S. remains a net exporter, but petroleum exports would just be lower.
  - The change in the U.S. energy import outlook results largely from the outlook for lower U.S. petroleum consumption and significantly increased domestic production from tight and shale oil resources.

- **The RFS distorts the market for refined products for merchant refineries**
  - Merchant refineries cannot offset their Renewable Identification Number (RIN)[6] obligation without making purchases from the RIN market because most of their sales are on the bulk level.
  - Unlike integrated refineries and chain marketers, the RIN obligation represents a net cost to the merchant refiners that has increasingly reduced their refining margin.

Section II of this report explains the modeling and analysis of the RFS using EVA-NEMS. Section III of the report then provides an in-depth analysis of issues specific to merchant refineries, with a focus on the east coast refineries. The final section of the report provides conclusions from the analysis and offers recommendations for future policy direction.

[6] EPA uses Renewable Identification Numbers (RINs) to track compliance with the RFS.

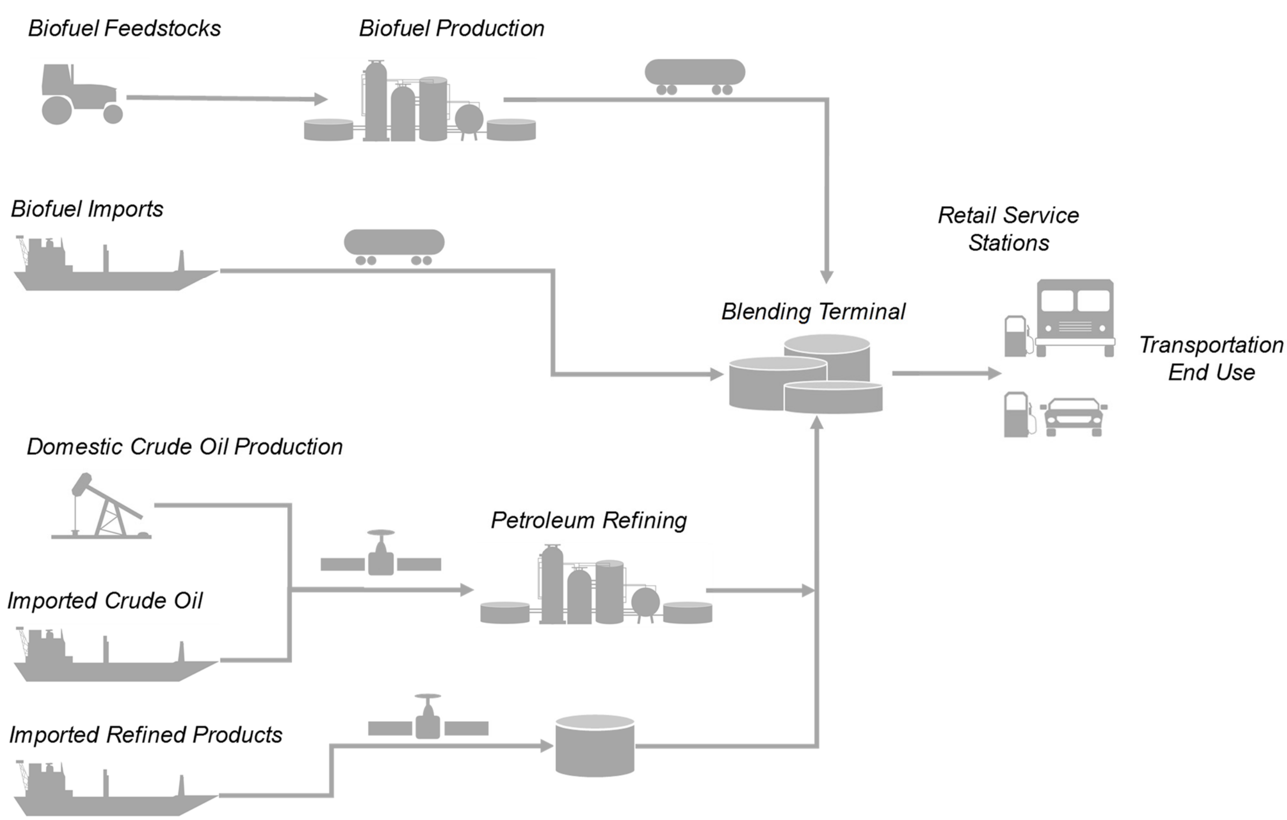
II. Modeling Outcomes of the RFS Using EVA-NEMS

EVA used the U.S. Energy Information Administration's (EIA) National Energy Modeling System (NEMS) to study the effects of different Renewable Fuel Standard mandates at the national level. The NEMS model is ideal for this analysis because it is specifically designed to evaluate the economic, social, and environmental effects of changes to energy resources, energy supply and demand technologies, and government policies that affect U.S. energy markets. Specifically, NEMS includes several submodules designed to represent the production and consumption of motor fuels including biofuels. This section describes the production, distribution, and consumption, the EVA-NEMS model that represents the system, the cases modeled, and the results.

The Production, Distribution, and Consumption of Motor Fuels

Most consumers filling up their cars and trucks at retail service stations are not aware of where their fuels originate, nor do they appreciate the complexity of the logistical system that has evolved over decades to bring that fuel to the pump. The overall production, distribution, and consumption of motor fuels consists of multiple supply chains that account for the unique aspects of each fuel type (e.g, motor gasoline and diesel), and components of each of these fuel types, as illustrated in Figure 1. This logistical system continues to change as the U.S. has increased exports of refined petroleum products[7] and, more recently, exports of crude oil.[8]

Figure 1 Overview of U.S. Motor Fuels Supply Chains



Source: Energy Ventures Analysis

[7] Matt French, "U.S. petroleum product exports set record high in 2018," *Today in Energy*, U.S. Energy Information Administration, April 23, 2019. https://www.eia.gov/todayinenergy/detail.php?id=39192.

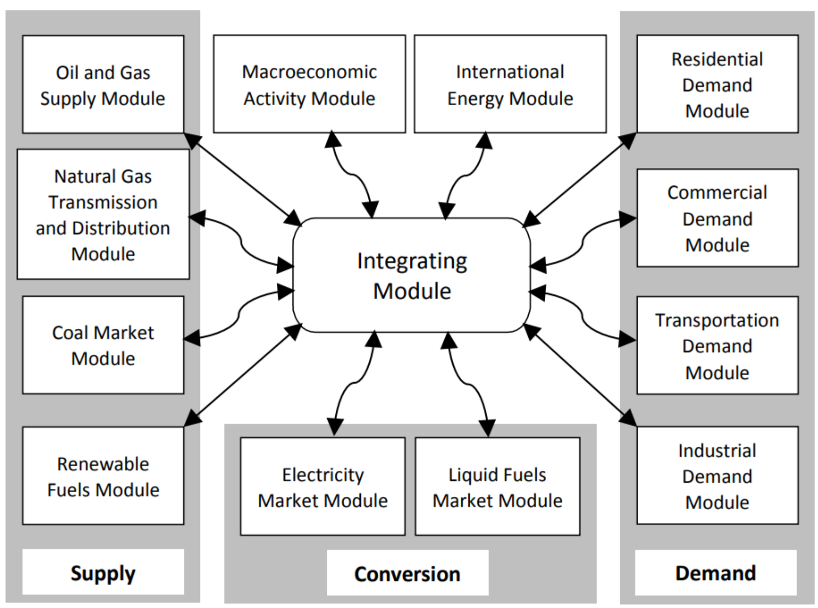
[8] Mason Hamilton, "The U.S. exported 2 million barrels per day of crude oil in 2018 to 42 destinations," *Today in Energy*, U.S. Energy Information Administration, April 15, 2019. https://www.eia.gov/todayinenergy/detail.php?id=39072.

The components of gasoline and diesel are brought together at blending terminals before distribution to retail fueling stations. Most gasoline is blended with 10 percent ethanol,[9] which must be brought separately to blending terminals because the geographic centers of production for each fuel are different, and because the alcohol-based chemical characteristics of ethanol prohibit its use in much of the petroleum-based transportation system.[10] For example, ethanol cannot be mixed with gasoline at a refinery and then sent to a terminal via pipeline. This difficulty arises because of ethanol's tendency to absorb water and separate from petroleum, to pick up sediments and impurities, and its corrosive effects on different materials. Biodiesel supply largely follows the same logistical pathway to blending terminals.

EVA-NEMS and Its Representation of Motor Fuels Production and End Use

The complexity of the production and consumption of motor fuels can be modeled in a framework that considers not only their unique characteristics but also that integrates these aspects with other sectors of the energy economy. The National Energy Modeling System (NEMS) is an integrated energy model that includes 12 modules covering domestic energy supply, conversion, and demand (Figure 2) that was developed by the U.S. Energy Information Administration (EIA). EIA uses NEMS to produce its Annual Energy Outlooks and to conduct policy analysis regarding the potential impacts of pending or proposed legislation, regulations, and standards.[11]

Figure 2 NEMS: Modular and Integrated Structure



Source: U.S. Energy Information Administration, *Integrating Module of the National Energy Modeling System: Model Documentation 2018.*

NEMS balances the energy supply and demand for each fuel and consuming sector, accounting for the economic competition between the various energy fuels and sources. Individual modules represent each of the fuel supply markets, conversion sectors, and end-use consumption sectors of the energy system. The primary flows of information between each of these modules are the delivered prices of energy to the end user and the quantities consumed by product, region, and sector. The delivered prices of fuel incorporate all the activities necessary to

[9] U.S. Energy Information Administration, "Almost all U.S. gasoline is blended with 10% ethanol," *Today In Energy*, May 4, 2016.
[10] E.g., NACE International, "Solving ethanol's corrosion problem may help speed the biofuel to market." *ScienceDaily* October 1, 2013; and https://primis.phmsa.dot.gov/comm/Ethanol.htm and https://www.quora.com/Why-can-t-ethanol-be-transported-by-pipeline.
[11] U.S. Energy Information Administration, *The National Energy Modeling System: An Overview 2009,* March 2009, p. 1. https://www.eia.gov/outlooks/aeo/nems/overview/pdf/0581(2009).pdf.

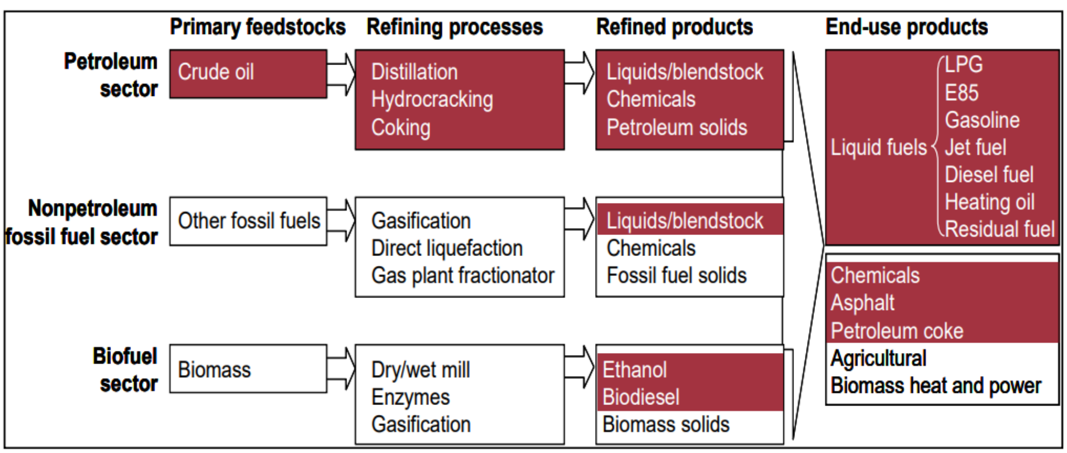
produce, import, convert, and transport fuels to the end user. The information flows also include other data such as economic activity, domestic production, competitive choice, and international petroleum supply availability.

NEMS is specifically designed to evaluate policies such as the RFS. Each NEMS sub-module is designed to represent impacts and costs of federal legislation and regulations that affect each sector including those policies and regulations that are defined sufficiently to be modeled, such as the Energy Independence and Security Act of 2007, which forms the basis of the current implementation of the Renewable Fuels Standard.

The modules of greatest interest for this analysis include the Liquid Fuels Market Module (LFMM) and the Transportation Demand Module (Tran). The LFMM models transportation fuels that meet vehicle and regulatory requirements from available feedstocks (e.g., crude oil, corn, etc.) using a linear programming (LP) formulation (Figure 3).[12,13] An LP model is the best tool for this purpose because the refining industry must consider using many different crude oils and other feedstocks to produce a broad slate of end-use products, among other factors.[14]

The Tran module represents different vehicle types, consumer preferences for making vehicle choices, and the availability of fueling stations.[15,16] As such, consumption of a specific fuel as represented in Tran is affected by its cost, the availability of the fuel to consumers, and the number of vehicles in use that can use that fuel. Tran can incrementally add fuel availability (i.e., what fuels are made available at fuel stations by region) and can change the types of vehicles available for purchase in response to consumer demand.

Figure 3 Liquid Fuels Production as Modeled Within LFMM Highlighted in Red



Source: U.S. Energy Information Administration*, Liquid Fuels Market Module (LFMM) of the National Energy Modeling System: Model Documentation 2018.*

[12] U.S. Energy Information Administration, *Assumptions to AEO2019: Liquid Fuels Market Module,* January 2019. https://www.eia.gov/outlooks/aeo/assumptions/pdf/liquidfuels.pdf.
[13] U.S. Energy Information Administration, *Liquid Fuels Market Module (LFMM) of the National Energy Modeling System: Model Documentation 2018,* July 2018. https://www.eia.gov/outlooks/aeo/nems/documentation/lfmm/pdf/m059(2018).pdf.
[14] OnLocation, Inc., *Liquid Fuels Market Model Component Design Report*, October 26, 2010. https://www.eia.gov/outlooks/documentation/workshops/pdf/LFMM%20CDR.pdf.
[15] U.S. Energy Information Administration, *Assumptions to AEO2019: Transportation Demand Module,* February 2019. https://www.eia.gov/outlooks/aeo/assumptions/pdf/transportation.pdf.
[16] U.S. Energy Information Administration, *Transportation Sector Demand of the National Energy Modeling System: Model Documentation,* March 2019. https://www.eia.gov/outlooks/aeo/nems/documentation/transportation/pdf/m070(2018).pdf.

EVA's Use of NEMS

To perform the modeling for this assessment, EVA obtained the version of NEMS that EIA used to produce its *Annual Energy Outlook 2019* (AEO2019). A large part of NEMS was developed directly by EIA and is therefore available in the public domain, meaning the source code and related files can be obtained directly from EIA.[17] EVA obtained the necessary third-party licenses to run NEMS and only made changes to the RFS mandate levels to conduct the analysis as described in this report.

All model results using the RFS mandate changes made by EVA are denoted as "EVA-NEMS." Therefore, the results presented in this report are not what EIA would say if requested to perform an assessment (sometimes referred to as a Service Report) of the RFS program. However, it could be expected that if EIA were asked to conduct such an analysis, the agency would likely employ NEMS to develop its response to such a request. For clarity, all NEMS model results produced by EVA are referred to as "EVA-NEMS" to distinguish them from those results produced by EIA. In addition, the results presented here are directly reproducible by others that operate NEMS.

The RFS Consists of Multiple Interrelated Biofuel Mandates

The RFS has four categories designed to increase the production of differing renewable fuels to achieve a level of 36 billion gallons by 2022.[18] The four categories are biomass-based diesel (consisting of biodiesel,[19] and renewable diesel[20]), cellulosic biofuel,[21] advanced biofuel,[22] and conventional renewable fuel. The cellulosic biofuel and biomass-based diesel mandates are *nested*[23] within the advanced biofuel mandate. The difference between the total RFS mandate and the advanced mandates can be met by *conventional* biofuels, which is sometimes referred to as the *implied corn ethanol* mandate.[24] An illustration of the *nesting* of the individual biofuel mandates is provided in Figure 4.

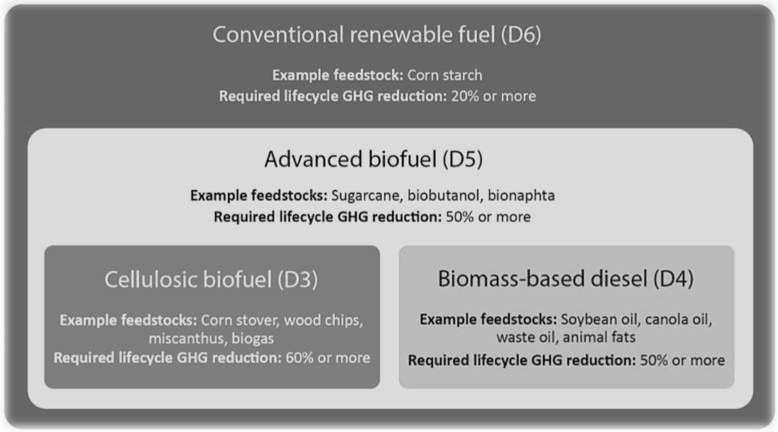
EPA is required to perform a review each year to set the RFS mandate levels through a notice of proposed rulemaking (NPRM), which it has done since 2010 with the acknowledgement that the cellulosic category of the mandate could not be met.[25] Until the most recent NPRM, EPA had boosted the advanced, and hence, the total mandate requirements by increasing the biomass-based biodiesel portion of the mandate to levels more than twice the volumes set in the original RFS schedule.[26] Appendix A provides the schedule of biofuel credits and volumes to be met through 2022 and shows how EPA set those credits and volumes over the years.

Currently the RFS's point of obligation is with refiners and fuel importers. The point of obligation defines the points in the motor fuels production, distribution, and consumption system, as shown in Figure 1, that firms are held accountable for complying with the RFS mandate (i.e., obligated parties). EPA uses Renewable Identification Number (RINs) that are designated by codes, referred to as D-codes, corresponding to each

---

[17] U.S. Energy Information Administration, *Availability of the National Energy Modeling System (NEMS) Archive,* January 2019.
[18] A program summary is available at https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard.
[19] Biodiesel is a fuel typically made from soybean, canola, or other vegetable oils; animal fats; and recycled grease that can serve as a substitute for petroleum-derived diesel or distillate fuel.
[20] Renewable diesel is diesel fuel and diesel fuel blending components produced from renewable sources that are produced stand-alone or co-processed with petroleum feedstocks and meet the requirements of advanced biofuels.
[21] Cellulosic biofuel is defined as a renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions at least 60% less than the baseline lifecycle greenhouse gas emissions.
[22] Advanced biofuels are defined as any renewable fuel (other than ethanol derived from corn starch) that has lifecycle greenhouse gas emissions at least 50% lower than baseline lifecycle greenhouse gas emissions.
[23] I.e., "included within." EPA and others generally use the term "nested" when describing the program.
[24] Jayson Beckman, Getachew Nigatu, *Global Ethanol Mandates: Opportunities for U.S. Exports of Ethanol and DDGS*, October 2017, U.S. Department of Agriculture, Economic Research Service. https://www.ers.usda.gov/webdocs/publications/85450/bio-05.pdf?v=0.
[25] U.S. Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule," *75 Federal Register 58*, p. 14675. https://www.govinfo.gov/content/pkg/FR-2010-03-26/pdf/2010-3851.pdf.
[26] Kelsi Bracmort, *The Renewable Fuel Standard (RFS): An Overview*, January 23, 2019, the Congressional Research Service, CRS Report R43325. https://fas.org/sgp/crs/misc/R43325.pdf.

Figure 4 The RFS Consists of Nested Mandates



Source: U.S. Environmental Protection Agency.

biofuel as indicated in Figure 4,[27] to track obligated parties compliance. Refiners and fuel importers are required to meet their obligation by submitting RINs based on the volume of gasoline and diesel they supply into the U.S. market according percentages determined by EPA (see Appendix B). As discussed above, the RIN requirement are nested (Figure 4), meaning that the lower-numbered RINs can count against compliance for higher-numbered RINs as follows:

- D5 (advanced biofuel) can count for D6 (conventional renewable fuel) compliance
- D3 (cellulosic biofuel) can count for both D5 and D6 compliance
- D4 (biomass-based diesel) can also count for both D5 and D6 compliance

For ethanol, RINs are created when ethanol is produced, but they are only usable as credits when the renewable fuel is blended into gasoline (i.e., "separated"). If a refinery or importer decides to blend the fuels themselves, RINs are generated to help meet their obligation. However, if the refinery or importer does not blend its own fuel, it must buy RINs from the market, often from blenders who blend in excess of their obligation. Some blenders have no obligation because they do not produce gasoline or diesel themselves. EPA data indicate these non-obligated parties represent a growing percentage of RIN separators—representing 15 percent of RIN separations in 2014 and growing to 24 percent in 2018.[28] Biodiesel producers, on the other hand, can separate RINs and sell them directly because their fuel is considered a diesel substitute.

The Four EVA-NEMS Cases

EVA specified four cases to highlight the different ways the RFS mandate levels affect the U.S. energy economy (Table 1). These cases are named and summarized as follows:

- **Reference**: EIA's *Annual Energy Outlook 2019* (AEO2019) Reference case.

- **No RFS**: The RFS mandate levels are dropped to zero after 2020, which in effect eliminates the whole RFS program.

[27] There are no D1 or D2 RINs.
[28] EPA EMTS data.

- **Plus 5%:** The total RFS mandate (i.e., the top-line RFS volume) is 5% higher than the level in EIA's reference case in 2025 and beyond. All other parts of the RFS mandate levels are held to EIA Reference case levels.

- **RFS Advanced**: The RFS total mandate is dropped to zero after 2020, and the biomass-based diesel mandate is held to 2019 levels. All other categories of the RFS mandate levels are the same as in the EIA Reference case.

These cases were developed to quantitatively assess the RFS and its effects on the U.S economy. The EIA Reference case published by EIA provides a baseline for analysis, and the No RFS case shows how much the RFS program is projected to cost consumers. EIA's Reference case itself includes assumed values for the RFS volumes EPA will set in future years. As a result, EIA states that the Reference case is based upon, "… RFS targets exogenously set by EIA analysts. The exogenously revised targets were set such that they could actually be achieved over the projection period."[29] In addition, EIA excludes the biogas component[30] of the RFS mandate. In reality, transportation fuel needed to meet this biogas component must be met by petroleum, because biogas is intended to be injected in a pipeline and used to fuel natural gas vehicles, which are a very small portion of the vehicle fleet. Therefore, biogas does not directly displace the consumption of motor fuels.

Two other cases in this report provide further insight into the projected effects of the RFS program. The Plus 5% case examines the impact of a slightly more stringent policy that aims to increase ethanol consumption. The RFS Advanced case examines what the RFS would look like if the mandates only supported the advanced biofuel production category. This case separates the goal of attaining a number as large as possible for the total RFS mandate from the other categories of the RFS mandate and reveals the effect of supporting higher corn ethanol production on the U.S. economy and on the levels of other biofuel production.

The EVA-NEMS Results

The EVA-NEMS results can be discussed from three different perspectives. First, the EIA Reference case itself reveals insights into the future of the RFS. Second, the effects of the RFS can be reviewed by considering the cases where the RFS is eliminated and if the RFS were to be pushed incrementally higher as compared to the Reference case. Finally, the Advanced RFS case that removes the pressure to push the total RFS mandate is reviewed. The results are discussed with respect to ethanol, biodiesel, and consumer impacts. The quantitative results of the EVA-NEMS cases for 2025 and 2030 with respect to volumes are shown in Table 1, with respect to prices and expenditures in Table 2, and with respect to new vehicle sales in Table 3.

Insights from the EIA Reference Case

The EIA Reference case provides several relevant insights into EIA's projection regarding the RFS. These insights include the following:

- Ethanol consumption is projected to decrease from 14.4 billion gallons in 2018 to 13.8 billion gallons and 13.3 billion gallons in 2025 and 2030, respectively, as shown in Table 1.
- The reduced ethanol consumption results from the lower consumption of motor gasoline that can be blended with ethanol (Table 1), decreasing from 143.2 billion gallons in 2018 to 128.1 billion gallons in 2025 and 117.1 billion gallons in 2030.
- Biofuels are projected to be no more than 11.3 percent of motor gasoline consumption by 2030.
- Electric vehicle sales will exceed the sales of Flexible Fuel Vehicles (FFV) by 2025, as shown in Table 3.
- EPA is assumed to push the biodiesel mandate to 3.2 billion gallons.

[29] U.S. Energy Information Administration, *Liquid Fuels Market Module of the National Energy Modeling System*, July 2018, p. 81.
[30] During 2014 EPA expanded the definition of what could be considered a cellulosic fuel under the RFS to include biogas, which can be produced from landfills, municipal waste water facility digesters, agricultural digesters, or separated municipal solid waste (MSW) digestors, and that produces compressed natural gas (CNG) or liquified natural gas (LNG) in *79 Federal Register 138,* July 18, 2014.

Table 1 Volumetric Effects of the EVA-NEMS RFS Cases in 2025 and 2030

	2018	2025				2030			
	Actual	Reference	No RFS	Plus 5%	Advanced RFS	Reference	No RFS	Plus 5%	Advanced RFS
RFS Mandate, billion credits [1]									
Total	19.0	17.5	0.0	18.4	3.9	17.0	0.0	17.9	3.9
Advanced	4.0	3.9	0.0	3.9	3.9	3.9	0.0	3.9	3.9
Cellulosic	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1
Biomass-based diesel	2.1	3.2	0.0	3.2	2.1	3.2	0.0	3.2	2.1
Implied corn ethanol	*15.0*	*13.6*	*0.0*	*14.5*	*0.0*	*13.1*	*0.0*	*13.9*	*0.0*
Volume, billion gallons									
Motor Gasoline	143.2	128.1	128.3	127.7	128.5	117.1	117.3	116.7	117.5
of which: E85	0.4	1.4	0.7	2.3	1.0	2.2	0.9	2.4	1.3
Diesel	60.6	56.1	56.2	56.1	56.2	54.9	55.0	54.8	55.0
Supply from Renewable Sources	16.9	16.6	14.0	17.3	15.6	16.0	13.2	16.6	14.8
Ethanol	14.4	13.8	13.4	14.3	13.6	13.3	12.5	12.8	12.8
Production	16.1	15.0	15.0	15.2	15.1	15.0	14.9	14.1	15.0
of which: Corn	15.6	14.5	14.7	14.7	14.1	14.5	14.5	13.6	14.0
Biodiesel	1.8	1.9	0.6	2.0	1.6	1.9	0.6	2.0	1.6
Domestic Production	1.8	1.3	0.0	1.4	0.9	1.3	0.0	1.3	1.0
Other Biomass-based Liquids [2]	0.5	0.8	0.0	1.0	0.4	0.8	0.0	1.8	0.4
of which: Biobutanol [3]	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.0	0.0
Corn in Biofuel, million bushels [4]	5,219	5,030	5,074	5,133	4,895	5,025	5,016	5,141	4,851
Biofuel share of Gasoline, % [5]	10.0%	10.8%	10.5%	11.2%	10.6%	11.3%	10.7%	11.8%	10.9%
Petroleum Imports, % [6]	11.7%	-12.0%	-11.1%	-12.4%	-11.5%	-17.6%	-16.4%	-17.8%	-16.9%
Change from Reference Case, billon gallons									
Ethanol & Biobutanol Consumed			-0.4	0.5	-0.2		-0.8	0.4	-0.5
Biodiesel Consumed			-1.3	0.1	-0.3		-1.3	0.0	-0.3
Corn-based Biofuel Production			0.1	0.3	-0.4		0.0	0.0	-0.5
Corn in Biofuel, million bushels			44	103	-135		-9	115	-175

Sources: U.S. Energy Information Administration *Monthly Energy Review*, *Short-Term Energy Outlook, AEO2019* Reference case, U.S. Department of Agriculture, U.S. Energy Protection Agency, and Energy Ventures Analysis EVA-NEMS No RFS, Plus 5%, and Advanced RFS cases.

[1] Excludes biogas.

[2] Includes pyrolysis oils, biomass-derived Fischer-Tropsch liquids, biobutanol, and renewable feedstocks used for the on-site production of diesel and gasoline.

[3] Biobutanol is blended into motor gasoline at levels up to 16 percent and counts as 1.3 credits per gallon in the RFS.

[4] Includes the corn used in the production of ethanol and biobutanol using yields of 2.89 gallons/bushel for ethanol and 2.22 gallons/bushel for biobutanol.

[5] Includes both ethanol and biobutanol.

[6] Includes the consideration of all petroleum products and liquid fuels such as biofuels. Also known as "net import share of product supplied."

Table 2 Price and Expenditure Effects of EVA-NEMS RFS Cases in 2025 and 2030, 2018$

	2018	2025				2030			
	Actual	Reference	No RFS	Plus 5%	Advanced RFS	Reference	No RFS	Plus 5%	Advanced RFS
Retail Transportation Prices, $/gallon									
Motor Gasoline	2.90	3.15	3.12	3.21	3.12	3.36	3.33	3.39	3.32
Diesel	3.18	3.47	3.37	3.58	3.38	3.76	3.65	3.80	3.67
Ethanol Production Cost	1.29	1.37	1.37	1.39	1.37	1.31	1.30	1.32	1.30
Motor Gasoline Wholesale	2.07	2.04	2.04	2.03	2.04	2.28	2.28	2.28	2.28
Corn price, $/bushel	3.47	3.75	3.77	3.82	3.74	3.47	3.47	3.52	3.45
Expenditures, billion dollars									
Motor gasoline	415	404	400	410	401	393	390	396	390
Diesel	193	195	190	201	190	206	201	208	202
Change from Reference Case									
Prices									
Motor Gasoline, cents/gallon			-3.4	5.8	-3.4		-3.0	3.5	-4.0
Diesel, cents/gallon			-9.4	11.1	-8.2		-11.1	3.9	-9.8
Corn Price, $/bushel			0.02	0.07	-0.01		0.00	0.05	-0.02
Expenditures on Motor Fuels, billion dollars			-8.7	12.2	-7.3		-8.4	4.6	-8.2
Motor gasoline			-3.7	6.2	-3.1		-2.9	2.8	-3.4
Diesel			-4.9	6.0	-4.2		-5.6	1.9	-4.8

Sources: U.S. Energy Information Administration *Monthly Energy Review*, *Short-Term Energy Outlook, AEO2019* Reference case, U.S. Department of Agriculture, and Energy Ventures Analysis EVA-NEMS No RFS, Plus 5%, and Advanced RFS cases.

Table 3 Total and Alternative Vehicle Sales in EVA-NEMS RFS Cases in 2025 and 2030, thousands

	2018	2025				2030			
	Actual	Reference	No RFS	Plus 5%	Advanced RFS	Reference	No RFS	Plus 5%	Advanced RFS
Total Vehicles Sales, thousands	15,694	15,194	15,219	15,219	15,219	15,448	15,420	15,420	15,420
Total Alternative Vehicles	3,545	6,222	6,279	6,382	6,272	6,663	6,587	6,712	6,583
Flexible Fuel Vehicles (FFV)	886	816	814	953	814	949	780	954	790
Electric	206	962	986	1,006	986	1,102	1,134	1,152	1,132
Plug-in Hybrid	176	292	292	294	292	331	332	335	331
Other [1]	570	694	690	697	690	845	840	847	840
Alternative Vehicles, %	23%	41%	41%	42%	41%	43%	43%	44%	43%

Sources: U.S. Energy Information Administration *Monthly Energy Review*, *Short-Term Energy Outlook, AEO2019* Reference case, and Energy Ventures Analysis EVA-NEMS No RFS, Plus 5%, and Advanced RFS cases.

[1] Includes gaseous, fuel cell, and electric hybrid vehicles.

EIA's projection of decreasing motor gasoline consumption through 2030 is noteworthy because that trend directly impacts the RFS. EIA states that the fuel efficiency of light-duty vehicles and light trucks will increase by 60 percent between 2018 and 2050. Therefore, the potential motor gasoline pool to blend ethanol into gasoline at up to 10 percent levels, known as E10,[31] is also projected to be decreasing over time.[32]

EIA projects that E85[33] consumption will increase to 2.2 billion gallons by 2030, which may be rather optimistic given the current low levels of E85 sales. EIA's optimism regarding E85 sales also shows up in the No RFS case where nearly one billion gallons of E85 are projected to be consumed even in the absence of an RFS mandate. However, even with this rather large increase in E85 sales, the projection still shows that ethanol consumption decreases in the EIA Reference case.

The increased mandated level for biodiesel is driven in part by EIA's assumption that the EPA will continue to raise the advanced and total mandate levels by continuing to raise the biomass-based diesel mandate, as discussed above. EIA projects that the biomass-based diesel category will be met by both biodiesel and by a large portion of what is listed as "Other biomass-derived liquids." This category includes pyrolysis oils, biomass-derived Fischer-Tropsch liquids, biobutanol, and renewable diesel.[34] Except for biobutanol, all these fuels qualify as biomass-based diesel.[35] For that reason, EVA lists the biobutanol portion of the "Other biomass-derived liquids" separately in Table 1.

The No-RFS and Plus 5% Cases Show the Range of RFS Effects

Comparing the results of the EVA-NEMS results for the No RFS case with results of the Plus 5% RFS case clearly shows that the RFS has large impacts on consumer expenditures, but small impacts on expanding the use of ethanol or in providing benefits to corn growers. Two alternative futures for the RFS are elimination or incrementally higher limits as compared with the Reference case. Results of these two alternative futures include the following:

- Consumers are projected to pay more than $8 billion more per year at the pump by 2025 if the RFS continues.
- Only minor variations in the use of biofuels in motor fuels are evident in the two cases.
- Only minor variations in corn consumption and corn prices are seen in the two cases.
- Domestic biodiesel production would drop to zero if the RFS were to be eliminated, unless the $1.00 per gallon federal tax credit for biodiesel is renewed.
- New vehicle sales are largely not affected in the two cases.
- The import share of petroleum is not significantly affected in the two cases.

Consumers would pay more at the pump in the Reference case as compared to the No RFS case

Consumers are projected to pay $8.7 billion and $8.4 billion more in 2025 and 2030, respectively, under the Reference case than if the RFS were eliminated, as shown in Table 2. Under the No RFS case, motor gasoline prices are projected drop by 3.4 cents per gallon and 3.0 cents per gallon in 2025 and 2030, while diesel prices are projected to drop by 9.4 cents per gallon to 11.1 cents per gallon in those same years. Prices for diesel

[31] E10 is gasoline with 10 percent ethanol content by volume.
[32] U.S. Energy Information Administration, *Annual Energy Outlook 2019*, January 24, 2019, pp. 107, 113.
[33] The three general categories of ethanol-gasoline blends are E10, E15, and E85. E15 is gasoline with 15 percent ethanol content, and E85 is a fuel that may contain over 15 percent and up to 85 percent fuel ethanol. All gasoline engine vehicles can use E10. Currently, only flexible fuel vehicles (FFVs) and light-duty vehicles with a model year of 2001 or newer are approved by the EPA to use E15. In addition, FFVs can use any ethanol-gasoline blends up to E85.
[34] U.S. Energy Information Administration, *Annual Energy Outlook 2019*, Table 11, footnote 5.
[35] Biobutanol is a 4-carbon alcohol (butyl alcohol) that is produced from the same feedstocks as ethanol, including corn grain and other biomass. See, for example: https://afdc.energy.gov/fuels/emerging_biobutanol.html.

consumers (e.g., trucking, rail, farming, etc.) would drop more than for gasoline consumers (e.g., households) if the RFS were to be eliminated.

Conversely, increasing the total RFS mandate by the relatively small amount specified under the Plus 5% case places an even greater burden on consumers. Consumers are projected to pay an additional $12 billion and $4.6 billion more in 2025 and 2030, respectively, under the Plus 5% case than the Reference case, as shown in Table 2. Motor gasoline prices are projected to increase by an additional 5.8 cents per gallon and 3.5 cents per gallon in 2025 and 2030, while diesel prices are projected to increase by 11 cents per gallon to 3.9 cents per gallon in those years.

The effects of lower prices and expenditure in the Plus 5% case over time are attributable to motor fuel prices rising to levels that make it economic to bring other types of biofuels to market, which results in the reduction in the additional amount the consumers are projected to pay at the pump. Biobutanol production increases from practically zero to one billion gallons in 2030 in the Plus 5% case as compared to the Reference case. The EIA NEMS model allows biobutanol made from corn feedstocks to be produced if prices warrant based on EIA's own assumptions about the future commercial viability of that fuel.[36] Biobutanol can, in turn, be blended into motor gasoline at levels up to 16 percent,[37] which overcomes some of the difficulties with increased ethanol consumption, as described below. Despite this slight increase in biofuels production and consumption, the cost to consumers remains significant.

There is little difference in the use of biofuels in motor fuels in the two cases

The results of the No RFS and Plus 5% cases show that U.S. corn-based biofuels production (ethanol and biobutanol) remain at nearly the same levels as in the EIA Reference case through 2030. As shown in Table 1, the consumption of ethanol and biobutanol decreases by 0.4 billion gallons and 0.8 billion gallons in 2025 and 2030, respectively, comparing the No RFS case with the Reference case. However, corn-based production is largely unchanged because domestic ethanol production costs are lower than the wholesale price of gasoline.

Figure 5 shows the projection of the delivered production cost of ethanol and the wholesale gasoline price[38] in the Reference and No RFS cases. The production cost of corn-based ethanol currently is (and is projected to remain) lower than the wholesale price of motor gasoline, which results in ethanol being economic to produce and blend into the motor gasoline pool. The fact that corn-based ethanol production costs have been lower than wholesale motor gasoline costs has been reported by EVA[39] and others.[40]

Corn consumption and prices differ very little in the two cases

The EIA Reference case projects that 5,030 million bushels and 5,025 million bushels of U.S. corn will be used in ethanol production in 2025 and in 2030. The No RFS case projects 5,074 million bushels of corn will be used in ethanol production in 2025, followed by 5,016 million bushels in 2030. The change in bushels of corn used in biofuel production between the Reference and the No RFS cases is positive by 44 million bushels in 2025 and negative by 9 million bushels in 2030. The change between 2025 and 2030 of less than one-half percent of the 14,420 million total U.S. corn bushels produced in 2018 is not significant.[41]

---

[36] U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2019: Liquid Fuels Market Module*, January 2019, pp. 12-13.

[37] Ibid, p. 5.

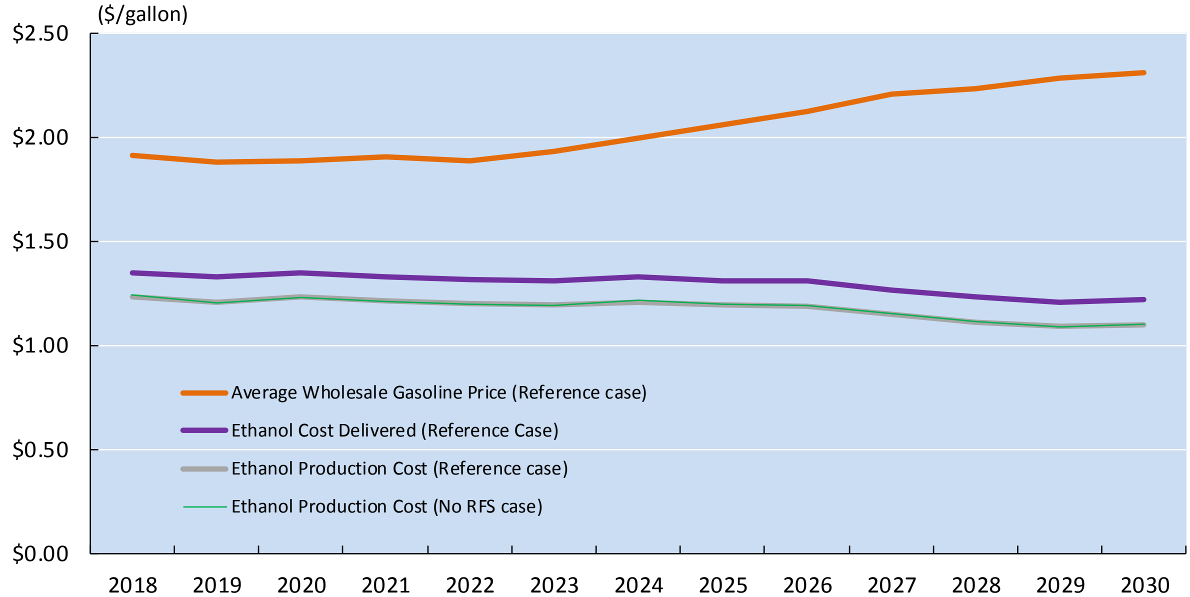
[38] For many regions, wholesale gasoline is known as reformulated blendstock for oxygenate blending (RBOB), which consists of motor gasoline blending components intended for blending with oxygenates, such as ethanol, to produce finished reformulated gasoline.

[39] A. Michael Schaal, letter to U.S. Department of Justice dated March 26, 2018 regarding PES Holdings, LLC., et al., U.S. Department of Justice Ref. No. 90-5-2-1-10993/1, p. 5.

[40] Steve Hanson, Sean Hill, "Positive U.S. ethanol margins are driving ethanol production growth," March 6, 2018 *Today in Energy,* U.S. Energy Information Administration.

[41] U.S. Department of Agriculture, *Crop Production 2018 Summary*, February 2019, ISSN: 1057-7823.

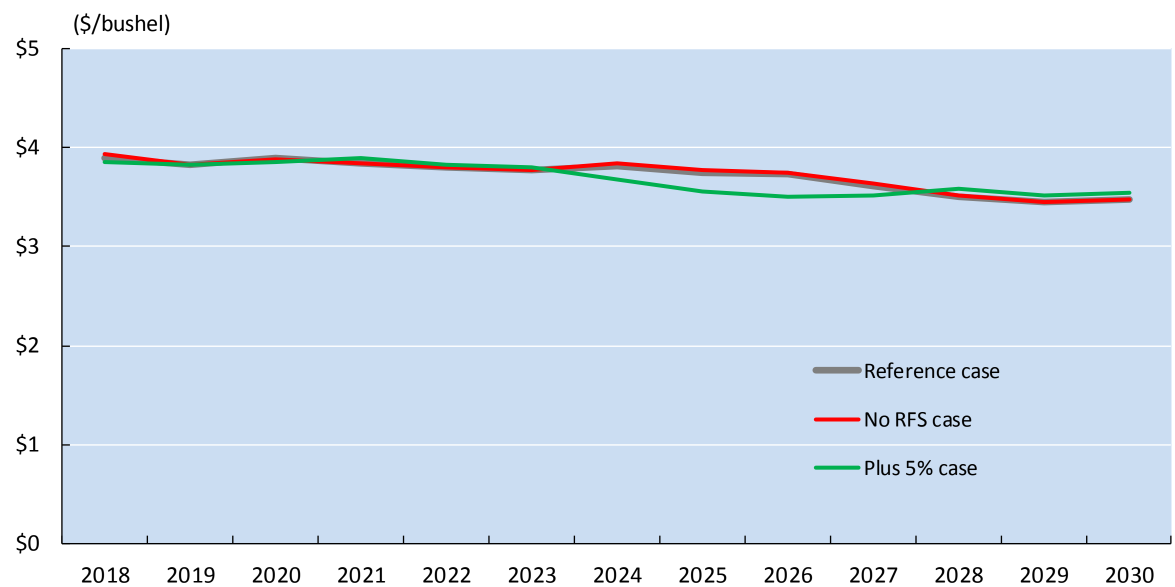
Figure 5 Projected Ethanol Production Costs Remain Below Wholesale Gasoline Price, 2018 to 2030



Sources: EIA AEO2019 Reference case and EVA-NEMS No RFS case.

The economics of ethanol production substantiate the model results that the RFS has a small impact on the level of corn used in biofuel. Correspondingly, the results show that the RFS also has a small impact on corn prices. The 2025 price of corn is $3.75, $3.77, $3.82, and $3.75 per bushel in the respective Reference, No RFS, Plus 5%, and Advanced RFS cases, respectively. Figure 6 shows that the corn price results for 2025 through 2030 are mixed, with corn prices only consistently increasing in the Plus 5% case. The No RFS case demonstrates that removing the RFS could lead to increased corn prices in 2025, because domestic production increases slightly to make up for the decline in ethanol imports that respond to the RFS. On the other hand, raising the total RFS mandate level leads to the introduction of, and increasing use of, other types of biofuels that qualify for the other categories of the RFS mandate, which then put competitive pressure on corn ethanol volumes and prices.

Figure 6 Projected Corn Prices Change Only Slightly Across EVA-NEMS Cases, 2018 to 2030



Sources: EIA AEO2019 Reference case and EVA-NEMS No RFS and Plus 5% cases.

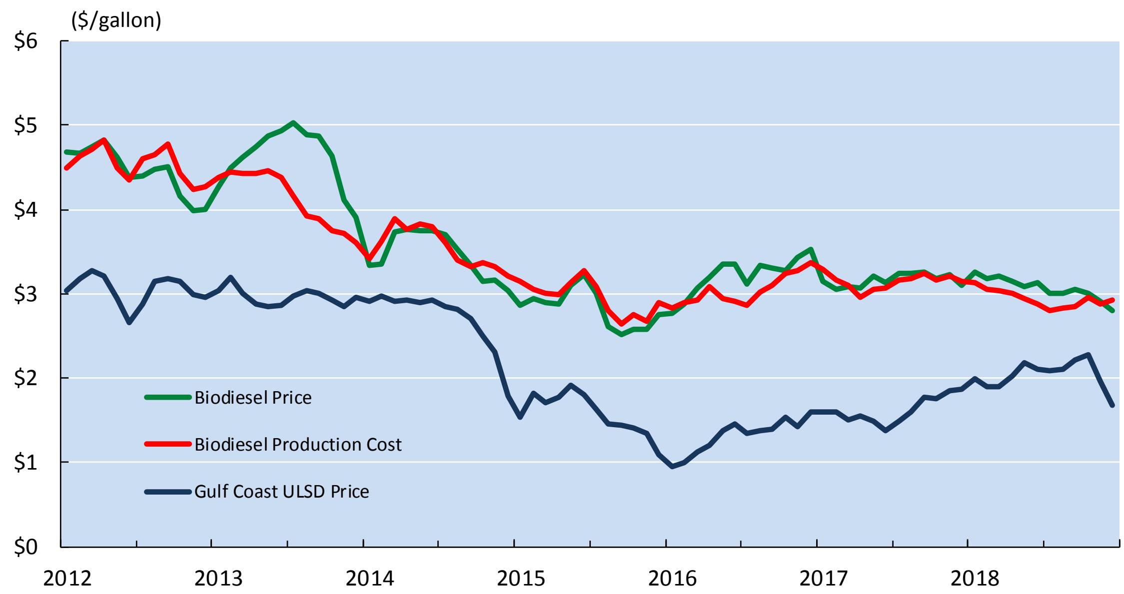
Domestic biodiesel production drops to zero in the No RFS case

The No RFS case shows that the domestic production of biodiesel drops to zero if the RFS were eliminated, as shown in Table 1. Unlike corn ethanol, domestic biodiesel production costs are not projected to be competitive with petroleum-based distillate production, particularly because the EIA assumes that the $1.00 per gallon biodiesel excise tax credit will not be extended.

The finding that domestic biodiesel production requires mandates, such as the RFS, and the biodiesel tax credit to remain operating is consistent with the historical production cost of biodiesel as compared to biodiesel prices and petroleum-based diesel prices (Figure 7). This figure shows that the production cost of biodiesel is higher than the price of petroleum-based diesel.

Biodiesel producers are more directly affected by policy decisions than corn growers and ethanol producers. Research performed by Dr. Scott Irwin shows the sensitivity of domestic biodiesel profitability to changes in the RFS and the relative cost of imported biodiesel.[42] As the RFS mandate is lowered, the effect is translated directly to biodiesel producer profits and volumes. On the other hand, domestic biodiesel pricing and production volumes have benefited from import duties that were imposed on Argentinian and Indonesian biodiesel imports as the result of the U.S. winning an anti-dumping petition with the International Trade Commission.[43] They have also benefited from the $1.00 per gallon federal tax credit, which could support domestic production in the future. Irwin notes that, given the tariffs and the market pricing in the tax credit, domestic consumption of U.S. produced biodiesel rose in 2018 and is projected to rise in 2019.

Figure 7 Monthly Biodiesel Production Costs Were Higher Than Diesel Prices, 2012 to 2018



Sources: U.S. Energy Information Administration and Iowa State University, *Biodiesel Profitability*, April 2019
Note: ULSD = Ultra Low Sulfur Diesel.

[42] Scott Irwin, "Biodiesel Production Profitability in 2018: Did Headwinds or Tailwinds Dominate?" *farmdoc daily* (9):54, March 27, 2019, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.
[43] Sean Hill, Neil Agarwal, "U.S. biomass-based diesel imports down for second consecutive year in 2018," April 30, 2019 *Today in Energy,* U.S. Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=39292.

Figure 7 emphasizes the significant cost of the biodiesel mandate. In fact, biodiesel has been between 60 cents and above two dollars more expensive than Ultra-Low Sulfur Diesel (ULSD) since at least 2012. This fact illustrates why the biodiesel mandate has been the most expensive part of the RFS. Based on 2018 actual prices, the biodiesel mandate cost consumers somewhere between $2.5 billion and $4.0 billion dollars.

The Advanced RFS case results in consumer savings for two main reasons: the implied corn ethanol mandate is eliminated and a more reasonable advanced mandate is assumed. As a result, consumers are not paying for the additional biodiesel that would be needed to bridge the gap between the 10 percent ethanol blendwall and the additional amount of unmarketable corn ethanol that would be required by an even higher conventional biofuels mandate.

New vehicle sales are largely not affected in any of the cases

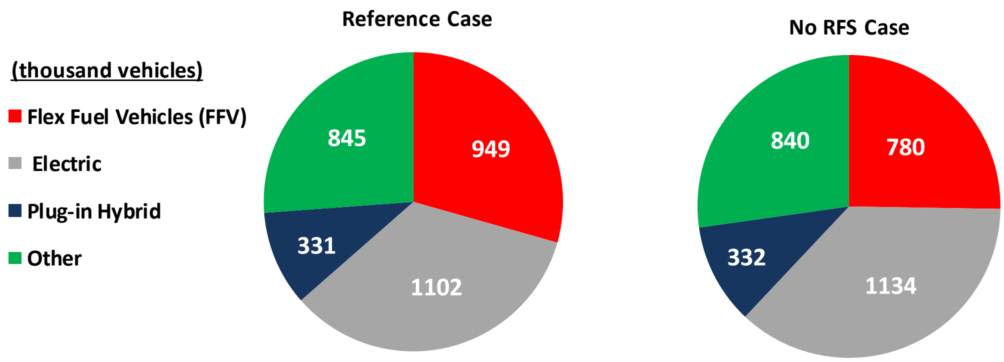
The EVA-NEMS results show little impact of changing RFS stringency on the composition of vehicle sales, as shown in Table 3. Under the RFS case, FFVs are expected to account for 13 percent of all alternative vehicles in 2025—down from 65 percent in 2015. Under the No RFS case, FFVs are also expected to make up 13 percent of all alternative vehicles by 2025. The impact of the RFS on FFVs as a percent of total alternative fuel vehicle sales in 2030 does not change significantly. In the reference case, FFVs make up 14 percent of alternative fuel vehicle sales by 2030. Increasing volume requirements to the Plus 5% case also leads to FFVs accounting for only 14 percent of all alternative fuel vehicles by that same year. By contrast, FFVs in the No RFS case are expected to make up less than 12 percent of total alternative fuel vehicle sales by 2030. The fact that FFV sales are not overly responsive to the RFS suggests other factors are shaping the alternative fuel vehicle market.

The finding that FFVs will not constitute a significantly larger share of vehicle sales—even under the Plus 5% scenario— reflects another issue regarding the future of RFS. In the Reference case, E85 consumption in the transportation sector is expected to increase by more than 1,200 percent from 2015 to 2030. FFV sales are expected to decline by 30 percent over the same period. Looking at the 2015 data, 0.015 quadrillion Btu of E85 were used in the transportation sector, and 1.4 million FFVs were sold. The Reference case expects 0.20 quadrillion Btu of E85 to be consumed annually by 2025. The same case anticipates FFV sales to decline to 912,000 FFVs, even as E85 consumption is projected to grow. Although the comparison is not perfect, given that vehicles sold are not the same as vehicle stock, a clear disconnect exists between assumed future E85 consumption under the RFS and the external factors shaping alternative fuel vehicle sales. The disconnect is even more relevant considering that many FFV owners may not even be aware of E85.[44]

Auto manufacturers are putting an increased emphasis on EV sales, and that trend is reflected in the different cases. In the EVA-NEMs results, electric vehicles (EVs)—not including hybrids and plug-in electric hybrids—are expected to grow from 2.6 percent of all alternative vehicles in 2016 to 15.5 percent in the Reference case by 2025. The growth in EV sales is also projected to increase in each of the EVA-NEMS cases which, again, are largely due to other factors shaping the alternative fuels market. Comparing results of the Reference case and the No RFS case for vehicle sales in 2030 (Figure 8) shows how the number of FFVs is expected to increase modestly in the reference case by 2030 but remain well below the 1.44 million FFVs sold in 2015.

[44] Stirling Kelley, "Government Flex-Fuel Vehicles Must Use E85 Where Available". December 2015. United States Navy, Navy News Service. https://www.navy.mil/submit/display.asp?story_id=92347
Martin Kaste, "'Flex-Fuel' Concept Fails to Deliver on Potential." December 2005. National Public Radio. WBEZ Chicago. https://www.npr.org/templates/story/story.php?storyId=5070205

Figure 8 Comparison of Alternative Fuel Vehicle Sales in the Reference and No RFS Cases in 2030



Sources: EIA AEO2019 Reference case and EVA-NEMS No RFS case.
Note: Other consists of gaseous, fuel cell, and electric hybrid vehicles.

Evidence exists outside the EVA-NEMS analysis that overcoming the RFS blend wall (i.e., marketing ethanol above 10 percent levels) would require both an infrastructure build-out to expand the marketing of ethanol blends beyond E10, such as E15 and E85, and a change in consumer behavior to buy these other products. As of 2018, about 1,065 fueling stations sold or were selling E15, paling in comparison to more than 150,000 fueling stations nationally.[45] The difference between the implied corn ethanol mandate (i.e., 15 billion gallons) and the current volume of ethanol production (14.3 billion gallons) implies a gap of about 700 million gallons. When E15 or E85 blends are sold instead of the standard E10, this gap is reduced. However, the current level of infrastructure and consumption is insufficient to have a meaningful impact on the blend wall. For reference, some industry experts have estimated that 175 million gallons of E15 will be sold in 2018—or roughly 1.2 percent of the total ethanol sold.[46] These E15 sales volumes will have created 8.75 million more new RINs than E10 would have—but that quantity is far short of the aforementioned 700 million RIN shortfall.

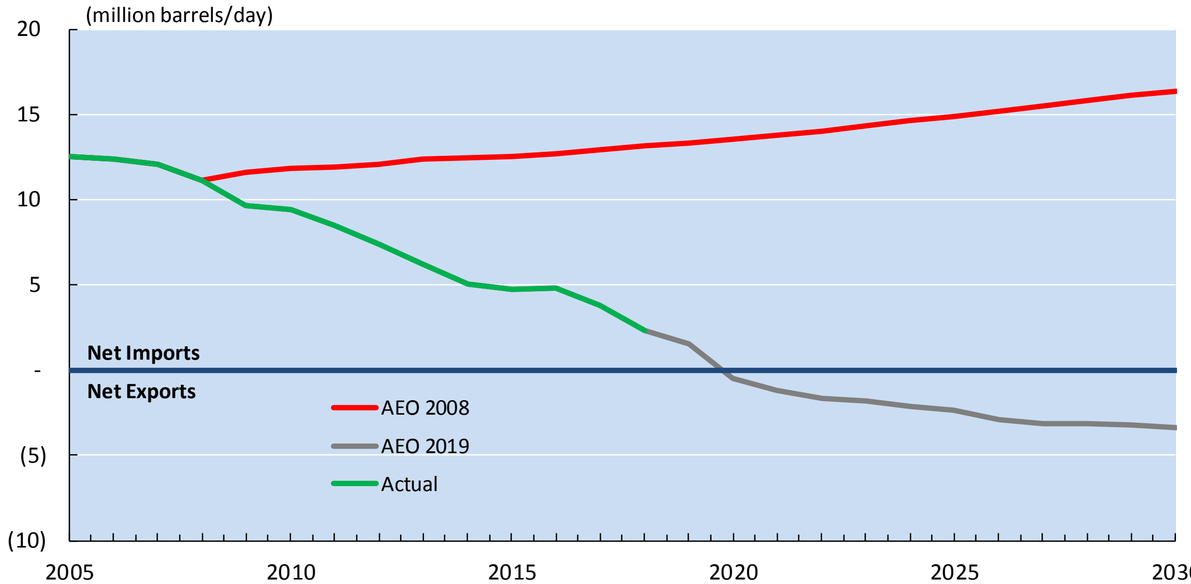
The import share of petroleum and other liquids is largely not affected

The RFS originated at a time when U.S. oil supply was much lower and when oil demand was expected to grow considerably. As of 2019, the U.S. is more energy secure in oil supply than it has been for several decades as shown in Figure 9. As a result of declining energy use and rapidly growing domestic production, the United States is expected to become a net exporter of energy within the next year.

Oil imports and exports are not a perfect measure of security due to the nature of international oil markets, but they do reflect that the U.S. is more energy secure than in the past. The EVA-NEMS results (Table 1, "petroleum imports") in the Reference case show that the U.S. net imports of petroleum and other products will equal negative 12 percent in 2025, meaning the U.S. will export 12 percent more petroleum than it consumes. In contrast, in the No RFS case, net imports of petroleum and other imports will be negative 11.1 percent of total consumption (i.e., exports). Elimination of RFS would change U.S. net import dependency on petroleum in 2030 by 1.2 percentage points, from negative 17.6 percent to negative 16.4 percent. The difference in petroleum dependence between the reference and no RFS case is not significant, given that the U.S. is expected to become a net exporter whether or not the RFS continues.

[45] "Year Round E15 Alone Will Not Contain RIN Costs," Fueling American Jobs Coalition. September 2018. www.fuelingusjobs.com/september-7
[46] "Year Round E15 Alone Will Not Contain RIN Costs," Fueling American Jobs Coalition. September 2018. www.fuelingusjobs.com/september-7.

Figure 9 Projected U.S. Net Petroleum Imports in AEO 2008 and AE0 2019, 2005 to 2030



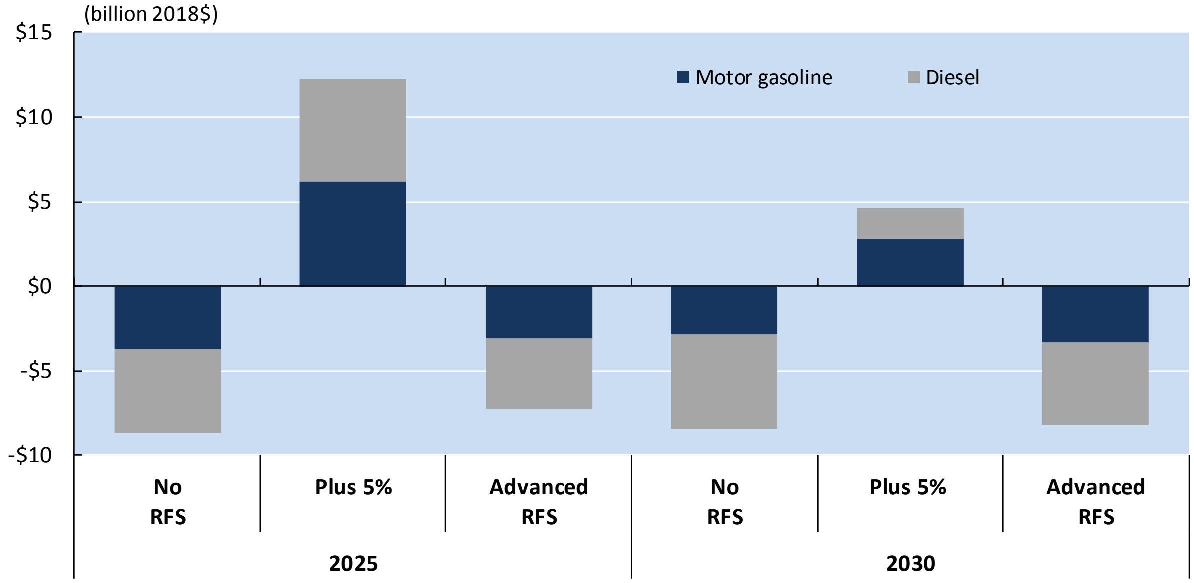
Sources: EIA, *Short-Term Energy Outlook*, AEO2008 *and* AEO2019 Reference cases.
Note: Net petroleum imports includes crude oil, petroleum products, petroleum blending components, biofuels, and hydrocarbon gas liquids (also known as natural gas liquids).

The Advanced RFS Case Provides Significant Consumer Savings by Focusing on Non-Ethanol Biofuels

The assessment of the RFS using the EVA-NEMS uncovered large costs to consumers and very little benefits for corn growers. A significant part of the costs at little benefit results from attempts to set the RFS mandate level as high as possible; despite the difficulties in achieving higher consumption levels of ethanol and production of biodiesel. Analysis of these results suggests that eliminating the conventional biofuel mandate would provide significant savings to consumers while also allowing for support to non-ethanol biofuels. EVA constructed the Advanced RFS case to quantify the effects of eliminating the implied corn ethanol mandate while also supporting to biodiesel producers using a biomass-based diesel mandate similar to levels achieved in 2018. The results of the Advanced RFS case are shown in Tables 1, 2, and 3.

The results reveal that most of the consumer benefits can be achieved by eliminating the RFS (No RFS case), as shown in Figure 10. Eliminating the implied mandate for corn-based ethanol as modeled by the Advanced RFS results in consumer savings of $7.3 billion and $8.2 billion in 2025 and 2030, as compared to the $8.7 billion to $8.4 billion that consumers would save under the No RFS case (Table 2). Biodiesel and other biomass-based liquids production would continue to be supported above the two billion gallon level. At the same time, the volumes of cost-competitive production of corn ethanol were largely unaffected (Table 1), and corn prices were largely unchanged (Table 2).

Figure 10 Annual Consumer Expenditures in EVA-NEMS and EIA Reference Case, 2025 and 2030



Sources: U.S. Energy Information Administration AEO2019 Reference case and Energy Ventures Analysis EVA-NEMS No RFS, Plus 5%, and Advanced RFS cases.

As previously stated, on a dollars-per-gallon basis the biodiesel mandate is the most expensive portion of the RFS. The Advanced RFS case leads to consumer savings because—in absence of an unachievable implied corn ethanol mandate combined with a more reasonable advanced mandate—consumers will not have to pay for biodiesel to bridge the blendwall gap. The blendwall gap is the gap between the volume of ethanol that can actually be consumed, given vehicle and infrastructure limitations, and the remaining volume that may be required by the implied corn ethanol mandate.

III. How the RFS Impacts Merchant Refineries

The previous sections evaluated the impacts of RFS at the national level. In reality, the differences in regional market dynamics often result in very different outcomes under the same national program. The NEMS model also does not distinguish different business models within the refining industry. This section zooms into PADD I (East Coast)[47] and demonstrates how the RFS program has created an uneven playing field for integrated versus merchant refineries in that region.

The business models for the integrated and merchant refineries are significantly different. To understand the difference, one must understand that transportation fuel sales occur at three levels: bulk, rack (wholesale), and retail. Bulk sales refer to large volume transactions that are "above the rack." Refineries sell bulk to marketers when the fuel is still in pipelines or terminal tanks. For an integrated refinery, the marketers they sell to are often owned by the same parent company. Marketers buy bulk fuel, blend it with biofuels, and then resell it at the wholesale level, in other words, at the rack. Tanker trucks load the blended fuel at the rack and transport the finished products to retail stations.

Integrated refineries own the entire supply chain from production to retail. An integrated refinery produces bulk fuel and also buys additional bulk fuel from the merchant refineries for blending. As a result, an integrated refinery often blends more fuel than it produces. The purchasing and blending functions are usually operated by the marketing arm of the integrated company. Because only fuel production/imports are subject to RIN obligations, integrated refineries not only generate enough RINs to cover their own bulk production, but they also can have excess RINs to sell to the market from blending the bulk fuel they bought, which can lead to a net RIN revenue. Because that integrated companies' market arm buys bulk fuel from merchant refiners, integrated refiners also have the incentive to resist merchant refiners attempts to pass on the RIN costs by raising bulk sale prices, because the pass-through represents additional buying costs for the integrated companies' marketing arm.

Other than integrated refineries, chain marketers can also own blending facilities, buy bulk from merchant refineries and generate RINs by blending fuels with ethanol. These marketers do not have any RIN obligation because they do not produce any fuels themselves. They also benefit from high RIN prices that boost their RIN revenue. For example, Murphy USA, a chain marketer that operates in PADD I-IV, owns blending facility and retail stations. As shown in Figure 11, its RIN revenue is almost the same as EBITDA in some quarters.

In contrast, merchant refineries mostly sell at the bulk level before blending. A merchant refinery could produce, blend, and then sell at the rack, but this is a very small proportion of its business, often less than 20 percent.[48] Because most of their sales are in bulk, merchant refineries do not generate many RINs, so they are subject to a net RIN cost. Merchant refineries would hope for low and stable RIN prices because the RIN obligation affects net profits. The RIN obligation has been a volatile cost for merchant refineries, and the percentage of RIN obligation to crack spread has grown which represents a burden on those refineries (Figure 12).[49] Merchant refineries on average purchased more than 80 percent of their RINs from the market. However, the RIN market has demonstrated poor market qualities including "high volatility, illiquidity, high transaction costs" as concluded in a 2018 NERA Economic Consulting report.[50] NERA also concluded that the RIN market is inefficient, fragmented, and creates incentives to engage in hoarding. Purchasing RINs is already

---

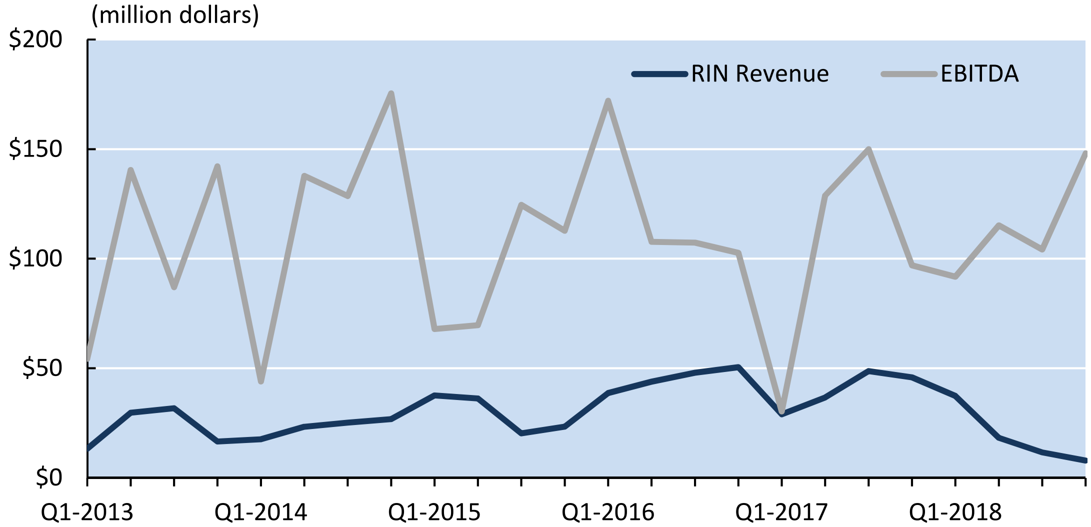
[47] PADD I, the East Coast region, includes states from Maine to Florida along the U.S. Atlantic Coast.

[48] EVA analysis of various merchant refineries' RIN compliance. See Appendix C.

[49] Calculated using a 2:1:1 crack spread.

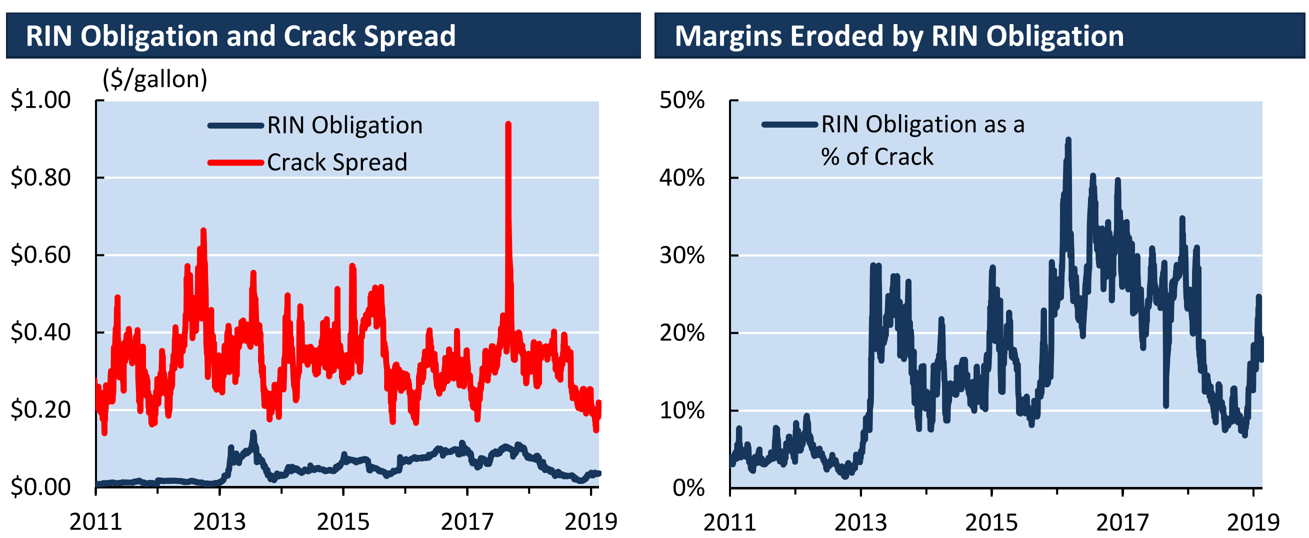
[50] NERA Economic Consulting, *Ethanol RIN Market Analysis and Potential Reforms,* October 18, 2018.

Figure 11 Murphy USA's RIN Revenue and Earnings, 2013 to 2018



Source: Murphy USA's 10Q reports.

Figure 12 RIN Obligations and the Crack Spread, 2011 to 2019



Source: EVA, NYMEX, OPIS, EPA.

Source: EVA.

a profit-burdening obligation for merchant refiners. Purchasing RINS from a volatile and unpredictable market further increases the cost of RFS compliance.[51]

[51] EPA proposed potential market reforms to improve the transparency of the market on March 12, 2019. The proposed reform includes: Prohibiting certain parties from being able to purchase separated RINs; requiring public disclosure when RIN holdings exceed specified thresholds; limiting the length of time a non-obligated party can hold RINs; and increasing the compliance frequency

Not only do production and blending activities at integrated refineries cancel out their RIN obligations, being able to blend and sell at the rack also enables them to realize more value for their CBOB and RBOB[52] production. Table 4 uses prices (E10, CBOB, Ethanol, blending, and transportation fee) at the racks in the Philadelphia area to demonstrate this advantage.

Table 4 Comparison of Realized Prices for CBOB at Merchant Refineries and Integrated Refineries[53]

Merchant Compared to Integrated Refinery				
	Average prices (cents/gallon)	Multiplier to scale to 9/10-gallon CBOB	Merchant refiners who cannot blend	Integrated refiners who produces CBOB and can blend
E10	173.1	1.00		173.1
CBOB	166.3	0.90	149.7	Implicit
Ethanol	144.8	0.10		-14.5
Terminal, additives, ethanol blending and transportation fee (per gallon of E10)	2.3	1.00		-2.3
RIN Generation	18.4	0.10		1.8
RIN Obligation	18.4	0.11*0.9	-1.8	-1.8
Realized CBOB value for 9/10 gallon			147.8	156.3
Scale back to 1 gallon of CBOB			**164.2**	**173.7**
Integrated Refiners' advantage per gallon of CBOB produced				**9.4**

Data source: OPIS.

Notes: Prices are weekly averages from January to April 2019. RIN prices are D6 prices. Prices represent the economics in the Philadelphia area in PADD I.

As shown in the Multiplier column in Table 4, one E10 gallon is made of 9/10 gallon of CBOB and 1/10 gallon of ethanol. In this example, a merchant refiner sells 9/10 gallon of CBOB to marketers who blend and sell a gallon of E10. From the trade, the merchant refiner receives 9/10 gallon of the per gallon CBOB price. However, every gallon of CBOB produced also creates an approximate 11 percent of RIN obligation.[54] As a result, the realized price for the merchant refiner's trade is 9/10 of the CBOB price minus the 11 percent RIN price, which averaged 147.8 cents from January to April 2019. Scaling this number to one gallon of CBOB, the merchant refiner netted 164.2 cents/gallon for its CBOB.

In comparison, an integrated refinery sells E10 after blending 9/10 gallon of CBOB with 1/10 gallon of ethanol. It produces the CBOB itself, which generates the same RIN obligation as for the merchant refiner. The integrated refiner, however, blends CBOB with ethanol and generates RINs, which offsets its RIN obligation. One can think of this as the marketing arm of the integrated refinery paying the refining arm of the integrated

of the program from once annually to quarterly. The comment period has ended on this proposal, although no decision has been made at the time of writing this report.

[52] CBOB refers to conventional blendstock for oxygenate blending. RBOB refers to reformulated blendstock for oxygenate blending. These blendstocks are intended for blending with oxygenates downstream of the refinery where it was produced. Fuel ethanol is one type of oxygenate.

[53] This study was inspired by and improved upon Bob Neufeld's study on PADD 4: https://www.rifoon.com/2018/02/05/prove-it/.

[54] 2019's percentage standard is 10.97 percent. See Appendix B.

refinery for the CBOB production. They can pay up to 173.7 cents/gallon and still break even in the example shown in Table 4.[55] Their realized CBOB prices are higher than the merchant refiner's realized price by 9.4 cents/gallon. Having the ability to blend and, therefore, have no net RIN cost, the integrated refiner receives more value for its CBOB production. It is important to note that the advantage shown in the example is not gained through better operations at the refineries but rather is created by the RFS program.

Unlike the integrated refineries, merchant refineries cannot offset their RIN obligation without making purchases from the RIN market because most of their sales are on the bulk level. Unlike integrated refineries and chain marketers, the RIN obligation represents a net cost to the merchant refiners that has increasingly reduced their refining margin. Buying RINs from the market can be costly because the RIN market is illiquid and volatile. Because integrated refineries are able to blend and offset their RIN obligations, the competition on fuel production is distorted and favors the integrated business model.

IV. Summary and Recommendations

The notion that a government policy can successfully and simultaneously support farmers, improve energy security, and promote the development of commercial lower carbon fuels with the RFS is admirable, but the program has turned out to be complicated, costly, and overcome by other events. Results from the EVA-NEMS modeling of the RFS show that the current implementation of the RFS mandate no longer supports the original goals of the policy. Specifically, the RFS is costly to consumers, provides meager-to-no benefits for corn growers, and is not a significant factor in U.S. energy security.

The EVA-NEMS results show that if EPA were to continue to push the RFS mandate in an attempt to meet a target that was set in 2007, households, truckers, and others would pay as much as $8 billion more at the pump in 2025. However, if the RFS were instead implemented so as to focus on more reasonable levels of non-ethanol biofuels that are not yet economic, consumers could then avoid having to pay a high price at the pump, and corn growers would maintain their current sales and pricing levels. These changes to the RFS would include eliminating the conventional biofuels mandate and limiting the biomass-based diesel mandate to moderate levels, which in this analysis are still more than double the levels specified in the RFS mandate. Lower levels of non-ethanol biofuels in the Advanced RFS scenario would likely result in even greater consumer and economy-wide savings.

Regarding implementation of the RFS, this analysis demonstrates that merchant refineries are at a significant structural disadvantage in the market. Obtaining RINs is a net cost for merchant refineries because most of their sales do not generate these credits. The position of merchant refineries differs from integrated refineries and chain marketers that can generate these credits through their own sales. At best, merchant refineries can hope for low and stable RIN prices, an outcome that is uncertain over the long term and unobtainable if RFS volumetric requirements are pushed further past the blendwall.

Based on these findings, EPA should seriously consider altering the mandates during the RFS Reset proceeding to acknowledge these larger market trends and their effects on the different fuel supply chains. Merchant refiners face high costs for compliance if EPA maintains its current RFS implementation policies. Households, truckers, and consumers also face higher costs. EPA should evaluate and reconsider the costs to consumers using tools such as those presented in this analysis to directly model the industry.

[55] E10 price minus 10% ethanol price, blending and transportation fee and RIN obligation plus RIN generation.

V. About the Authors

A. Michael Schaal

A. Michael Schaal directs EVA's petroleum practice. He has 30 years of experience in modeling, analysis of energy markets, and the development of energy projects. Prior to rejoining EVA, Michael was the Director of the U.S. Energy Information Administration's Office of Petroleum, Natural Gas and Biofuels Analysis. Among his responsibilities were producing the oil and natural gas and biofuels projections for EIA's Short-Term Energy Outlook and Annual Energy Outlook. Michael's prior experience also includes working as a professional engineer with Bechtel Corporation of San Francisco where he was involved in economic analysis, engineering, construction, and operations of first-of-a-kind facilities. Michael received his B.S. in electrical engineering from California State University in 1986 and his Master's degree in Mineral Economics from Pennsylvania State University in 1995.

Skylar Drennen

Skylar is a senior analyst focused on transportation, renewable energy, and emerging technologies. Skylar leverages his policy and economics background to track and quantify how developments in the electric vehicle or distributed energy spaces impact the broader power sector. Skylar also tracks energy policy at the state and federal levels to inform EVA's modeling assumptions. Skylar's previous work for Washington lobbying and energy security advocacy group, Securing America's Future Energy, focused on the impact of electric and autonomous technologies in the transportation sectors as well as how policies such as the Zero Emissions Vehicle mandate impacts state-level electric vehicle markets. Skylar received his B.A. in International and Global Studies from Middlebury College, and his M.A. in International Policy and Economics from Johns Hopkins University.

Appendix A Renewable Fuel Standard Mandate Volumes, 2010 to 2022

Table 5 Renewable Fuel Standard Targets, billion credits

Year	Total Renewable Fuel		Total Advanced Biofuels		Cellulosic Biofuel		Biomass-Based Diesel		Conventional Biofuel	
	Statutory Target	Actual Target	Statutory Target	Actual Target	Statutory Target	Actual Target	Statutory Target	Actual Target	Statutory Target	Actual Target
2010	12.95	12.95	0.95	0.95	0.10	0.0065	0.65	1.15	12.00	12.00
2011	13.95	13.95	1.35	1.35	0.25	0.0060	0.80	0.80	12.60	12.60
2012	15.20	15.20	2.00	2.00	0.50	0.0105	1.00	1.00	13.20	13.20
2013	16.55	16.55	2.75	2.75	1.00	0.0008	≥ 1	1.28	13.80	13.80
2014	18.15	16.28	3.75	2.67	1.75	0.0330	≥ 1	1.63	14.40	13.61
2015	20.50	16.93	5.50	2.88	3.00	0.1230	≥ 1	1.73	15.00	14.05
2016	22.25	18.11	7.25	3.61	4.25	0.2300	≥ 1	1.90	15.00	14.50
2017	24.00	19.28	9.00	4.28	5.50	0.3110	≥ 1	2.00	15.00	15.00
2018	26.00	19.29	11.00	4.29	7.00	0.2880	≥ 1	2.10	15.00	15.00
2019	28.00	19.92	13.00	4.92	8.50	0.4180	≥ 1	2.10	15.00	15.00
2020	30.00	TBD	15.00	TBD	10.50	TBD	≥ 1	2.43	15.00	TBD
2021	33.00	TBD	18.00	TBD	13.50	TBD	≥ 1	TBD	15.00	TBD
2022	36.00	TBD	21.00	TBD	16.00	TBD	≥ 1	TBD	15.00	TBD
2023 +	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Source: U.S. Environmental Protection Agency.

Notes:

1. TBD = To Be Determined.
2. The RFS legislation specifies the standard in volumes of "credits," which are counted as "ethanol-equivalent" gallons for each type of biofuel. The exception is Biomass-Based Diesel where the volumes are specified as gallons of that fuel type.
3. Ethanol-equivalent gallons for each type of biofuel is determined by multiplying its volume by an "equivalence value" that is determined largely by the energy content of that biofuel relative to ethanol. Example equivalence values: Ethanol = 1.0; Biodiesel = 1.5; Biobutanol = 1.3.
4. The Total Renewable Fuel category includes Total Advanced Biofuels and Conventional Biofuel.
5. Total Advanced Biofuels includes the categories Cellulosic Biofuels and Biomass-Based Diesel, with the gallons of the latter converted to ethanol-equivalent gallons. This category also includes imported sugarcane ethanol and biobutanol.
6. Cellulosic biofuels include fuels derived from nonfood-based feedstocks like grasses, agricultural residues, and wood wastes. This category includes cellulosic ethanol, renewable diesel, renewable gasoline, and biogas.
7. The Biomass-Based Diesel mandate volume for 2020 was set by EPA in the same rulemaking that set the 2019 levels for the other biofuel categories.
8. The Conventional Biofuels category consists of ethanol produced from starches and is almost entirely met by corn ethanol. This category can also include biofuels that would have counted in the Total Advanced Biofuels category but exceeded the mandate set for that year.

Appendix B Industry RIN Obligations as a Percentage of Motor Fuels Sold

Table 6 RFS Percentage Standard to the Volume of Motor Fuels Sold, 2013 to 2019

Year	Renewable Identification Number (RIN) Categories, %				Total RIN Obligation, %
	D3	D4	D5	D6	
2013	0.004	1.130	0.490	8.120	9.740
2014	0.019	1.410	0.100	7.680	9.190
2015	0.069	1.490	0.130	7.900	9.520
2016	0.128	1.590	0.292	8.090	10.100
2017	0.173	1.670	0.537	8.320	10.700
2018	0.159	1.740	0.471	8.300	10.670
2019	0.230	1.730	0.750	8.260	10.970

Source: U.S. Environmental Protection Agency.

Note: The percentage standards represent the ratio of the national applicable volume of renewable fuel volume to the national projected non-renewable gasoline and diesel volume less any gasoline and diesel attributable to small refineries granted an exemption prior to the date that the standards are set.

Appendix C How Merchant Refineries Meet Their RIN Obligation

In 2019 EVA conducted a survey to analyze the channels merchant refineries use to meet their annual RIN obligation. Merchant refineries participating in the survey have operations across the U.S., with a concentration of these refineries along the East Coast. The combined motor gasoline sales from participants companies was 5.3 billion gallons in 2018. By comparison, total U.S. motor gasoline consumption was 143 billion gallons in 2018, with the East Coast (PADD I) consuming 50.3 billion gallons in that year. In many of the regional markets, production from these refineries accounts for a large percentage of the motor fuels supplied to consumers.

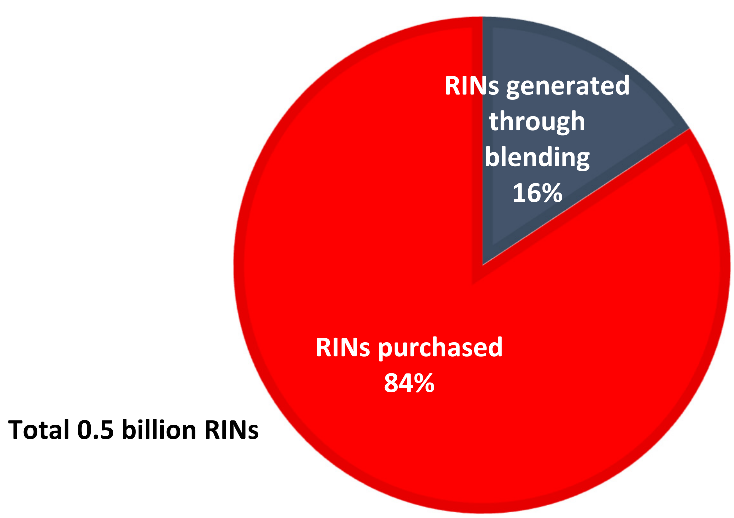
Data collected from 2017 and 2018 show that the refineries submitted 407 million RINs and 527 million RINs in 2017 and 2018, respectively. Only 77 and 83 million of those RINs were generated through blending in 2017 and 2018 respectively, less than 19 percent and 16 percent of the respective year's total RIN obligation (see Table 7). More than 80 percent of the RINs were purchased on the market (see Figure 13).

Table 7 How Merchant Refineries Meet Their RIN Obligations

RIN Compliance Breakdown		
(in millions)	2017	2018
RINs generated through blending	77	83
RINs purchased	330	444

Source: EVA analysis of participating merchant refinery data.

Figure 13 Surveyed Merchant Refineries' Source of RINs in 2018



Source: EVA analysis of participating merchant refinery data.