Renewable Identification Number (RIN) Market Assessment and Retrospective

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Technical Report
NREL/TP-6A20-61813
August 2015

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Preface

Please <u>DO NOT DISTRIBUTE</u> the content of this NREL analysis report outside NREL, ORNL, INL, or DOE.

Please <u>EXERCISE CAUTION</u> when using contents from this report. The Renewable Identification Number (RIN) market is rapidly evolving and this report's content may become out of date. Also, some external reviewers consider the topic of the RIN market, and therefore, this report (particularly Section 2), to be highly "sensitive". This report is primarily based on a review of publicly available data and literature, but external reviewers expressed concerns that those data sources do not capture a 'well-balanced' perspective of the RIN market due to the limitation of published research.

Acknowledgments

This work was funded by the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) and Bioenergy Technologies Office (BETO). The authors wish to thank the following individuals for their thoughtful comments, input, and review of the document in its various stages: Laura Vimmerstedt, Emily Newes, and Kristi Moriarty of the National Renewable Energy Laboratory (NREL); Steve Peterson of Lexidyne and The Peterson Group. We also wish to thank Kendra Palmer of NREL for her editorial support.

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Acronyms and Abbreviations

American Society for Testing and Materials	ASTM
American Fuel and Petrochemical Manufacturers	AFPM
Clean Air Act	CAA
Compressed natural gas	CNG
Energy Independence and Security Act of 2007	EISA 2007
EPA's Moderated Transaction System	EMTS
Energy Policy Act of 2005	EPAct 2005
Environmental Protection Agency	EPA
Low carbon fuel standard	LCFS
Methyl tertiary butyl ether	MBTE
Billion gallons per year	bgy
Liquefied natural gas	LNG
Million gallons per year	mgy
Notice of violation	NOVs
Reformulated gasoline	RFG
Production tax credits	PTCs
Renewable Fuel Standard	RFS
Renewable Fuel Standard – 2	RFS2
Renewable identification number	RIN
Renewable volume obligation	RVO
System dynamics	SD
Uniform commercial code	UCC
Willingness to pay	WTP

Executive Summary

In 2011, the Environmental Protection Agency (EPA) implemented the Renewable Fuel Standard 2 (RFS2) program, a credit trading system along with biofuel volumetric mandates. The RFS2 establishes specific volumetric requirements for four overlapping or "nested" categories of biofuels: renewable, advanced, biomass-based, and cellulosic. Compliance with these requirements is tracked through renewable identification numbers (RINs), which are numbers that are used to identify specific fuel volume by category. The RIN market is complex relative to other credit trading systems with four categories of credits each corresponding to a RIN biofuel category. Other trading systems often have a single category of tradable permit.

The RIN market has recently experienced large rapid price swings in renewable fuel RINs. Developments in the RIN market pose potential opportunities and challenges to the transportation fuel industry. For example, opportunities could include incentives for the production of biofuels such as biogas and challenges such as policy compliance costs.

This report explores what policies, economic factors, and externalities influence RIN market prices, thereby affecting the biofuel industry through 2013. It summarizes and analyzes the legal, regulatory, and historical contexts of the RIN market and the existing research on the RIN market. We achieve this by:

1. Providing a comprehensive summary of the legal context for the RIN marketplace
2. Describing historical drivers of RIN market dynamics
3. Characterizing areas on this topic upon which future modeling and quantitative analysis can further build.

The future of the RFS2 program (and the RIN market) will be determined largely by the extent of the EPA's authority under the RFS2 program, and related Congressional action that could change that authority. Challenges have both constrained and more clearly established the EPA's authority: in *American Petroleum Institute (API) v. EPA*, the D.C. Circuit vacated the EPA's 2012 cellulosic biofuel projection, forcing the EPA to use an "outcome-neutral" methodology.

The D.C. Circuit let stand the EPA's use of decision not to reduce the total advanced biofuel volumetric mandate after reducing cellulosic biofuel volumetric mandates. This maintains the EPA's authority to reduce RFS2 volumetric mandates if justification is given, such as production capacity being insufficient to meet EISA legislated volumes. The EPA's decision to reduce advanced and renewable fuel volumetric mandates in its 2014 proposed rule will inevitably be challenged in court. Regardless of the outcome, the decision will have a large impact on the future of the RFS2 program.

The RFS2 program (and RIN market) may also be impacted by legislation amending the program. For example, based on proposed legislation, the RFS2 program could be amended to require the EPA to reduce renewable fuel and advanced biofuel when it reduces cellulosic biofuel; prohibit the EPA from raising allowable ethanol content of gasoline above 10%; or otherwise modify, repeal, or phase out the RFS2 program altogether.

Literature has examined many of the historic drivers of the RIN market. The major drivers of RIN market prices include:

- Biofuel market conditions relative to petroleum fuels as determined by many other secondary drivers, such as feedstock prices and the 10% blending limit to the use of ethanol with gasoline (i.e., the blend wall)
- The volumetric level of mandated use of biofuels, related to the RFS2 program and EPA's annual implementation of that legislation
- EPA's regulations, such as the nested structure of different categories of RINs. A RIN from within the nesting of RIN categories can be used to meet RFS2 program requirements for all RIN categories further out in the nest of RIN categories. Therefore market prices of RIN categories are interlinked.
- RIN market participant expectations about the above drivers. Changes in expectations have led to price volatility.

The RIN market has historically had limited influence on ethanol markets, specifically on commercial ethanol blending. Until around 2012, the RFS had little effect on ethanol blending due to underlying favorable economics supporting ethanol blending for many blenders. Then the blend wall—the point at which the E10 market is saturated—began to limit additional blending of corn-based ethanol. As a result, exports of corn-based ethanol may be higher than they would have been otherwise. RIN market prices could potentially encourage investment in infrastructure for higher ethanol blends; however, a sustained high RIN market price is one necessary precondition to influence infrastructure development.

The RIN market has had more implications for other biofuels besides ethanol. The opportunity exists to use advanced biofuel and biomass-based diesel RINs to meet renewable fuel mandates above the blend wall, as these fuels are not limited by the blend wall. Potential impacts on these fuels include increased imports, greater use of existing production capacity, and increased production from alternative biofuel systems (e.g., renewable diesel and biogas).

The RIN market has historically had a few other notable implications. The RIN market primarily functions as an economic transfer from petroleum fuel producers who need to purchase RINs to biofuel blenders and producers who sell RINs generated from the production of biofuels. RINs have served as an indirect crop price support that benefits biofuel feedstock producers via biofuel producer's willingness to pay for their feedstocks. To date, literature suggests that RIN prices have had a negligible impact on gasoline prices.[1] RIN markets are more likely to have affected diesel fuel prices, but this has not been well studied.

Past modeling and analyses have focused on retrospectively determining the drivers of RIN markets and the impacts of the RIN market. Prospective analysis has generally been short-term and focused on only minor changes to policies. There are many modeling and analysis opportunities related to more prospective research into longer-term issues related to changes in

[1] Increasing the volume of biofuels used in the transportation system will increase prices if the biofuels cost more on an energy-equivalent basis than the petroleum fuels they displace. This is an effect of the RFS itself rather than the RIN market.

policies, major RIN market regime changes, and scenario analysis of alternative contextual conditions, such as petroleum fuel prices. We recommend researchers focus on modeling and analysis in the following three key areas:

- Assessment of the RIN market's impacts on biofuel systems other than corn ethanol which has been the focus recent study
- Scenario analysis of the impact on biofuels markets of potential changes in policies, RIN market shifts in price drivers, and evolving contextual conditions such as petroleum fuel prices
- RIN market participant behavior analysis to better understand responses to potential changes (e.g., policy) that would affect the market.

The above recommended research pathways are not exhaustive, but focus on addressing key research gaps identified from the literature review. They are also likely to be important to understanding how the RIN market can or could influence the development of the biofuels market in the future.

Report Update - Major RIN Market Developments starting in 2014 and through July 2015

The analysis scope of this report includes data through 2013 and literature through the first few months of 2014. In 2014 several major RIN market-related developments occurred. These developments are impacting or will potentially affect the RIN market and the biofuel industry. This section updates this report by noting major developments.

Over the course of 2014 RIN market prices remained fairly steady relative to the prices shown in this report for the end of 2013 (see Figure 3.12) around $0.50/RIN. Biomass-based diesel, advanced biofuel, and renewable fuel RIN market prices increased moderately (i.e., by ~$0.20/RIN) near the beginning of 2014 and have declined gradually by the same amount throughout most of 2014. Near the end of 2014 and going into early 2015, RIN prices increased moderately to about $0.75/RIN (Irwin 2015). The price spread between biomass-based diesel and renewable fuel RIN market prices has ranged from ~$0 to ~$0.30/RIN in 2014 and 2015 (Irwin 2014b).

EPA published final regulations for a RIN quality assurance program in July 2014 (EPA 2015c). Section 2.4.3 of this report documents the proposal EPA was considering. The general proposal as presented in Section 2.4.3 was finalized as described. Details of the quality assurance program in the final regulations differ from the initial proposal based on public comment.

In 2014 EPA approved several new fuels pathways for generating cellulosic biofuel RINs. These pathways include those producing biogas for mixing with natural gas (at <75%) for liquefied natural gas (LNG) and compressed natural gas (CNG). Biogas-related fuel systems have generated over 15 million cellulosic biofuel RINs since this policy change in July (EPA 2015d). Prior to the policy change biogas was classified as an advanced biofuel.

Recent developments related to biogas have important future implications for cellulosic biofuel RIN market prices. EPA is required to permanently reduce the cellulosic biofuel mandate in 2016 based on conditions in legislation as described in Section 2.2.4.4 of this report. Wavier credits currently driving cellulosic biofuel RIN market prices would no longer be available if EPA reduces the mandate below the RFS EPA sets for 2016. Under these conditions the cellulosic biofuel RIN market price will instead be influenced by the costs of biofuels qualifying as cellulosic biofuel (i.e., biogas). Biogas could play a major direct role in cellulosic biofuel RIN market prices and an indirect role in the RIN market prices of other biofuel categories.

In November 2014, the EPA announced it would delay setting a 2014 RFS (as required by legislation) until 2015 (EPA 2015c). In August 2014 EPA extended the compliance deadlines for the 2013 RFS until the publication of the final rule establishing the 2014 RFS (EPA 2015c).

In April 2015 the EPA reached a proposed consent decree in litigation brought against the EPA by the American Petroleum Institute (API) and American Fuel and Petrochemical Manufacturers AFPM) for EPA's non-compliance with its nondiscretionary obligation under the Clean Air Act to issue Renewable Fuel Standards. The decree established a timeline for issuing Renewable Fuel Standards for 2014 and 2015. The decree stated the EPA would propose volumetric requirements for 2015 by June 1, 2015 and would finalize volumetric requirements for 2014 and 2015 as well as resolve a pending waiver petition put forth by API and AFPM for 2014 by November 30, 2015 (EPA 2015c; U.S. District Court 2015). In addition, the EPA stated that outside of the scope of the decree, the EPA committed to proposing and finalizing the 2016 RFS and the biomass-based diesel volume requirements for 2017 within the same June 1 and November 30, 2015 timeframes (EPA 2015c).

In May 2015 the EPA released the proposed volumetric requirements for 2014, 2015, 2016 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel, along with the 2017 requirements for biomass-based diesel (EPA 2015c). Similar to the original 2014 proposed rule (see section 2.3.4), the EPA is proposing to use its general waiver authority because of an “inadequate domestic supply” (see section 2.2.4.1) along with its cellulosic biofuel waiver authority (see section 2.2.4.2) to lower annual volumes below the statutory levels set by Congress in the Energy Independence and Security Act of 2007 (EISA 2007) (Pub. L. 110-140) (EPA 2015e). The EPA’s use of these two waiver authorities is meant to address two constraints:

1. Limitations in the volume of ethanol than can be consumed given the constraints on the supply of higher ethanol blends to the vehicles that can use them (i.e., the blend wall).

2. Limitations in the ability to produce sufficient volumes of qualifying renewable fuel, particularly non-ethanol fuels (EPA 2015e).

Of note, for 2014 the EPA is proposing to set the volumetric requirements at the levels that were actually used as transportation fuel, heating oil or jet fuel in the contiguous U.S. and Hawaii (EPA 2015e).

In September 2014 the EPA issued a Notice of Violation (NOV) to Global E Marketing, LLC and charged them with generating more than 6 million invalid biomass-based diesel (D4) RINs without importing any qualifying renewable fuel and transferring the majority of the invalid RINs (“Civil Enforcement” 2015).

In March 2015 the EPA filed a civil complaint against Washakie Renewable Energy, LLC and filed a Stipulation of Settlement and Order that resolved allegations that Washakie generated more than 7.2 million invalid biomass-based diesel RINs. The EPA does not plan to request that obligated parties who used the invalid Washakie RINs replace those RINs because Washakie retired replacement RINs (“Civil Enforcement” 2015).

Section 1. Introduction

In 2005, the U.S. Congress passed the Energy Policy Act of 2005 (EPAct 2005), which established the Renewable Fuel Standard (RFS1). In 2007, the U.S. Congress passed the Energy Independence and Security Act of 2007 (EISA 2007) (Pub. L. 110-140). This act was intended to increase U.S. energy independence and reduce greenhouse gas (GHG) emissions (U.S. Congress 2007). It amended the Clean Air Act (CAA) (42 USCS § 7401 et seq.) to require the U.S. EPA to promulgate rules mandating volumetric targets for several new biofuel categories. In 2011, the Environmental Protection Agency (EPA) implemented the Renewable Fuel Standard 2 (RFS2) program in order to implement EISA 2007 requirements.

This RFS2 program expanded the RFS1 program to increase the volume of renewable fuels required under RFS1, include diesel fuel substitutes in addition to gasoline, and establish new categories of renewable fuel, each with separate annual volumetric mandates ("Renewable Fuel Standard" 2013). EISA 2007 also amended the CAA to require the creation of a trading market for credits generated through biofuel production.

Researchers anticipated that increasing volumetric targets would begin to have impacts on RIN credit prices (Thompson et al. 2012; Irwin and Good 2013c). In 2013, the RIN market underwent rapid increases and decreases, purportedly related to decreases in gasoline demand, ethanol blending restrictions, and issues with startup cellulosic biofuel refineries. Developments in the RIN market pose potential economic and policy challenges and opportunities for meeting the transportation fuel industry's RFS2 volumetric mandates, and may have implications for the biofuels industry.

Regulatory regimes, such as RFS2, can have a major influence on biofuel economics and outcomes (Jeffers, Jacobson, and Searcy 2013) and have the potential for creating market barriers and distortions (Nicol and Seglins 2012; Drajem and Parker 2013; Emery 2012). RIN price volatility may persist, and perhaps increase, as bioenergy industries mature and their regulatory and techno-economic environments evolve (Donahue, Meyer, and Thompson 2010). This volatility could be further complicated by disruptive external influences such as international trade in biomass and biofuels (NREL 2013a; NREL 2013b), the emergence of high-value biomass-based products (plastics, acrylics, etc.), and petroleum prices. Understanding how RIN markets behave and continue to affect the prospects of biofuel technological pathways and biomass feedstock development is critical for effective bioenergy policy analysis and decision making—now and as the industry develops further.

The overall goal of this report is to provide a retrospective understanding of the RIN market and its historic and potential future role in influencing the development of the biofuel industry. To that end, we:

1. Describe in detail the legal and regulatory context surrounding the RIN market (Section 2)
2. Analyze the historic drivers of RIN prices
    a. Summarize historic trends and developments in the RIN market itself and related fuel markets (e.g., petroleum fuel) (Section 3)

    b. Summarize insights from the literature on how the RIN market responds to changes in policy and other related markets (Section 4)
    c. Present analysis of key issues, observations, tested and candidate hypotheses, and prospects regarding the determinants of RIN prices. Analysis was guided by literature and based on historic data (Section 5)
3. Recommend approaches for follow-on analysis and modeling of RIN credit markets (Section 6).

Section 2. The Legal and Regulatory Context of the RIN Market

Preface

Please <u>*EXERCISE EXTREME CAUTION*</u> *when using the contents of this section (highlighted in light grey). Section 2 is primarily based on publicly available documentation of the law, rules, court cases, and published legal analysis. Some external reviewers expressed disagreement with the interpretations cited or presented in this section.*

2.1 Overview

Section 2 provides an overview of the statutory and regulatory framework of the RFS program to consolidate all of the information related to the RIN market in one location.[2]

Section 2 focuses primarily on the RFS2 program (42 USCS § 7545(o)), which authorized the EPA to implement various provisions of the statute including setting volumetric mandates for renewable fuels for years beyond those expressly provided for in the statute, waiving volumetric mandates for years provided for in the statute, and creating a credit market for renewable fuels used to demonstrate compliance with the RFS2 volumetric mandates (i.e., the RIN market).

The EPA implements its congressionally delegated authority under the RFS2 through rulemaking procedures culminating in the promulgation of EPA regulations. As discussed in greater length in Section 2.3, these regulations must be within the scope of congressionally delegated authority and comply with the United States Constitution, the Administrative Procedures Act (APA), and judicial interpretations thereof.

This chapter addresses the major aspects surrounding the RFS2 program, including:

- The statutory framework of the RFS2 program and associated EPA regulations in furtherance of the RFS2 program
- The EPA's authority under the RFS2 program and the limitations of its authority under principles of administrative law
- The EPA's proposed 2014 Standards for the RFS2 program
- RIN fraud and the EPA's proposed rulemaking in response to RIN fraud
- Proposed legislation to amend the RFS2 program.

2.2 The RFS2 Program and EPA Regulations

The information provided in Section 2.2 is necessary for proceeding to discuss the legal and regulatory context of the RIN market as well as the other sections of this report.

This section discusses the statutory framework of the RFS2 program as enacted through EISA and the EPA's regulations found in 40 CFR § 80.1400 et seq. The statutory framework and EPA regulations cover a large breadth of topics including EPA's authority and process for establishing

[2] This report does not review or analyze the legislative history of the EISA (2007) except where relevant to court cases discussed in section 2.3.

the fuel volume requirements, setup of the credit (i.e., RIN) system, and exceptions to the RFS2 program.

2.2.1 Legal and Regulatory Definitions and Mathematical Representation of the RIN Market

Appendix A defines key terms found within EISA and the EPA's regulations; it also includes definitions for biofuel categories, regulated entities under the RFS2, and other aspects of the RIN market system.

Appendix B summarizes a mathematical representation of the definitions and constraints of the RIN market as laid out by the legal and statutory context in Section 2. The mathematical representation provides some clear definitions, constraints on the RIN market, and relationships between RIN market participants.

Definitions included in the mathematical representation summarize the major RIN biofuel categories and the types of participants in the RIN market, such as obligated parties and biofuel producers. Constraints on RIN market biofuel categories and participant behavior are made explicit in the mathematical representation. Section 2.2 expands on the mathematical representations in Appendix B.

2.2.2 Volumes of Renewable Fuels

EISA requires the EPA to promulgate regulations to ensure that gasoline sold or introduced into commerce in the United States contains the applicable required volume of biofuels on an annual basis (42 USCS § 7545 (o)(2)(A)(i)). In addition, EISA requires the EPA to revise regulations to ensure that this transportation fuel contains at least the applicable specified volumetric mandates of total renewable fuel (D6), advanced biofuel (D5), cellulosic biofuel (D3), and biomass-based diesel (D4) as shown in Figure 2.1 (42 USCS § 7545 (o)(2)(A)(i)). Regulations contain compliance provisions applicable to refineries, blenders, distributors, and importers.

The categories of biofuels are "nested" (see Figure 2.1) with biomass-based diesel (D4) and cellulosic biofuel (D3) counting towards the required volume of advanced biofuel (D5), and the required volume of advanced biofuel (D5) counting towards the required volume of total renewable fuel (D6) (42 USCS § 7545 (o)(2)(B)) (42 USCS § 7545 (o)(2)(A)(i)). Figure 2.2 provides the applicable volumes for each fuel category as specified in EISA.

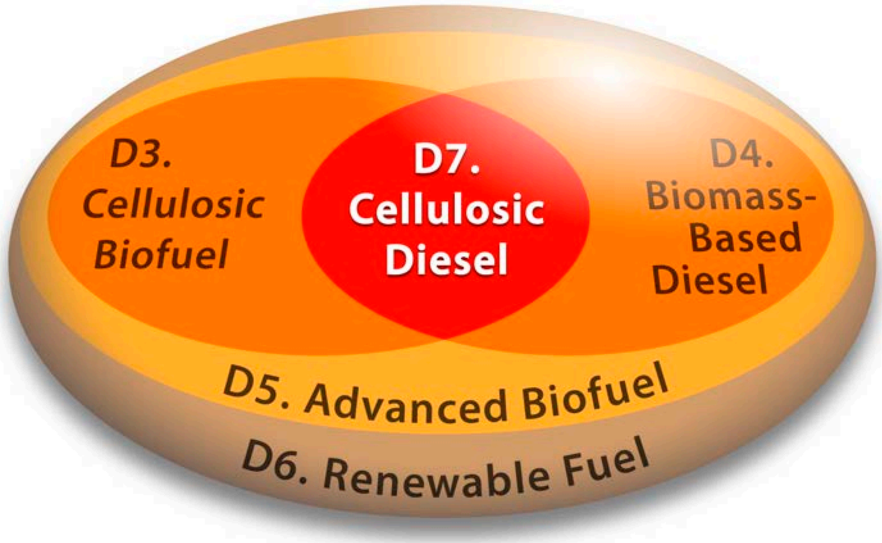

Figure 2.1. Nesting of biofuel categories under the RFS

See Appendix A for definitions for each biofuel category. Cellulosic biofuel (D3) and biomass-based diesel (D4) are both nested within advanced biofuel (D5), which is nested within renewable fuel (D6).
It is worth noting that cellulosic diesel (D7), while not an official fuel category under the RFS2, can count towards either cellulosic biofuel or biomass-based diesel, but the same fuel cannot count towards both requirements. (Diagram not to scale.)

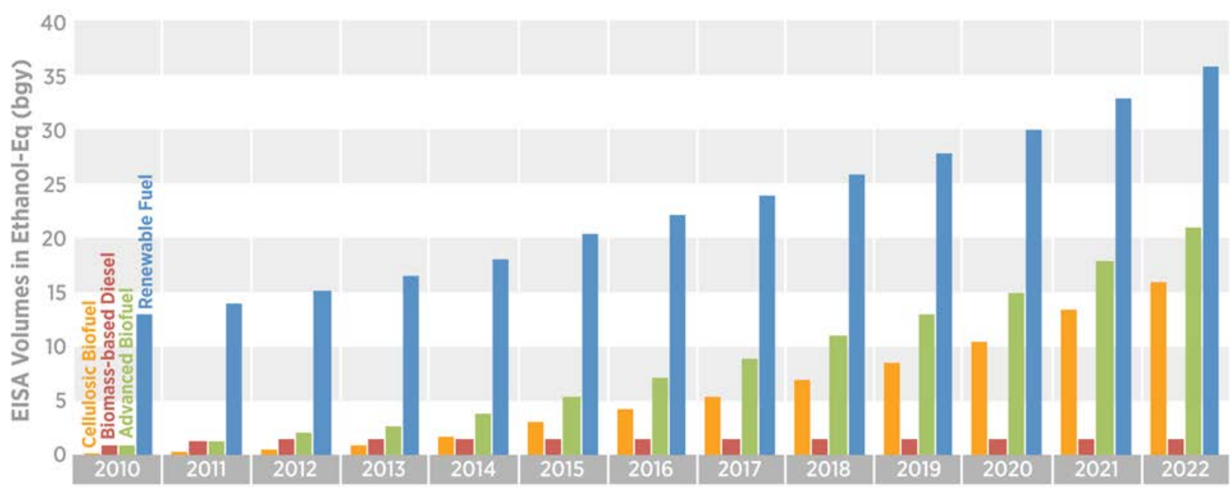

Figure 2.2. Annual EISA renewable fuel volumetric mandates (billion gallons of ethanol-eq per year) for four biofuel categories from 2010-2022

Source: 40 CFR § 80, Table A.I.1-1

For 2005-2021, EISA requires the Energy Information Administration (EIA) to provide the EPA with an estimate of the volumes of transportation fuel, biomass-based diesel (D4), and cellulosic biofuel (D3) that the EIA projects will be sold or introduced into commerce for the following year (42 USCS § 7545 (o)(3)(A)).

Based on the EIA estimate, the EPA must determine and publish the RFS (percentage) for that calendar year applicable to refiners, blenders, and importers (42 USCS § 7545 (o)(3)(B)). In addition, the EPA must promulgate regulations providing annual volumetric mandates:

- For years beyond those in which EISA specifies an annual RFS for the biofuel type (discussed in the next paragraph)
- When the EPA waives an annual volumetric mandates listed in EISA (discussed further in Section 2.4)
- When a waiver by the EPA requires a modification of the volumetric mandate for future years (discussed further in Section 2.4.4) (42 USCS § 7545 (o)(2)(B)(ii)) (42 USCS § 7545 (o)(7)).

For years beyond those for which EISA specifies an annual volumetric mandate for the biofuel type, the EPA determines the annual RFS in coordination with the Secretary of Energy and Secretary of Agriculture (42 USCS § 7545 (o)(2)(B)(ii)). In determining annual RFSs for years beyond those listed in EISA, the EPA reviews the implementation of the RFS2 program for years for which EISA specifies an annual volumetric mandate and analyzes a list of factors, including:

- The impact of the production and use of biofuels on the environment
- The impact of biofuels on the energy security of the United States
- The expected annual rate of future commercial production of biofuels
- The impact of biofuels on the infrastructure of the United States
- The impact of the use of biofuels on the cost to consumers of transportation fuel and the transportation of goods
- The impact of the use of biofuels on factors such as job creation, price and supply of agricultural commodities, rural economic development, and food prices (42 USCS § 7545 (o)(2)(B)(ii)).

EISA places a number of restrictions on the EPA's determination of RFSs for years not specified in EISA:

1. The volume of advanced biofuel (D5) must be at least the same percentage of the volume of renewable fuel (D6) as specified in 2022 (42 USCS § 7545 (o)(2)(B)(iii))
2. The EPA's determination of the volume of cellulosic biofuel (D3) must assume the EPA will not issue a waiver (42 USCS § 7545 (o)(2)(B)(iv))
3. The volume of biomass-based diesel (D4) must be no less than the volumetric mandate for 2012 (42 USCS § 7545 (o)(2)(B)(v)).

Figure 2.3 provides RFSs (bars) and original EISA mandated volumes (lines) for each fuel type as promulgated in the EPA's annual regulation.

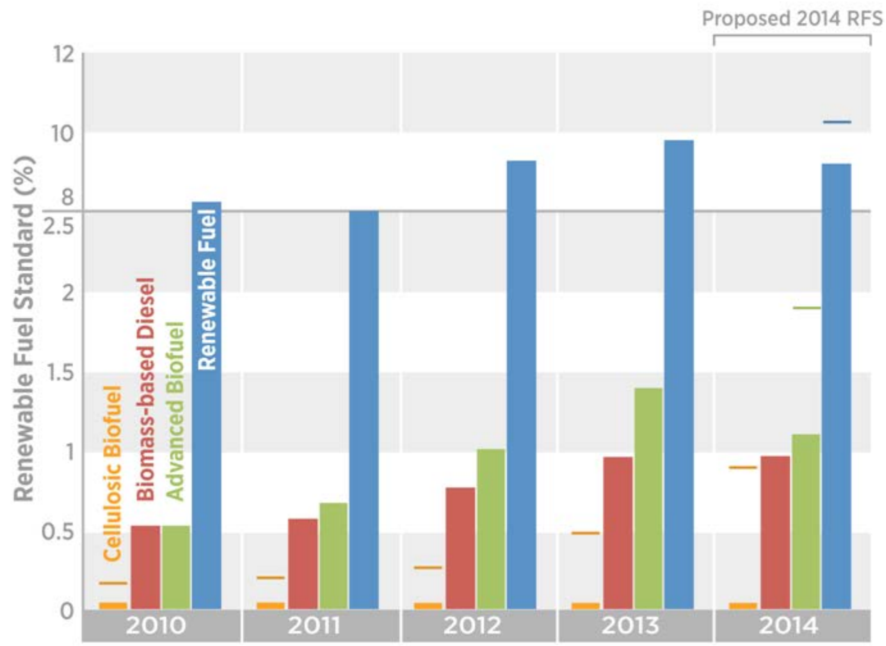

Figure 2.3. Annual EPA-promulgated volumetric mandates (%) for four biofuel categories.

Bars represent RFSs and lines represent the original volumetric mandate if EPA waived part of the mandate in setting the RFS.[3] The RFS percentage is used by obligated parties to calculate renewable volume obligations (RVO) relative to their total petroleum fuel (i.e., gasoline and diesel) production or imports (EPA 2013c; EPA 2013d; EPA 2013e; EPA 2011c; EPA 2010d; EPA 2010e).

2.2.3 RIN Credit Program

EISA requires the EPA to promulgate regulations creating a credit program to ensure that the RFS2 volumetric mandates discussed in Section 2.2.2 are met, and to provide for the generation of credits by any person that refines, blends, or imports gasoline that contains a greater quantity of biofuel than required to meet volumetric mandates, for the generation of credits for biodiesel, and for the generation of credits by small refineries if they waive the small refinery exemption (42 USCS § 7545 (o)(5)(A)). In addition, EISA allows the EPA to promulgate regulations for the generation of credits by any person that refines, blends, or imports additional biofuels as specified by the EPA (42 USCS § 7545 (o)(5)(E)).

EISA further requires (or, in the case of additional biofuel, permits) the regulations to allow a generator of credits to either use the credits for compliance or transfer the credits to another person for compliance with the volumetric mandates (42 USCS § 7545 (o)(5)(B)) (42 USCS § 7545 (o)(5)(E)).

EISA limits the duration of the credits to 12 months as of the date of generation, which the EPA regulations specifically allow the RIN to be used to show compliance in the current year and the following calendar year (42 USCS § 7545 (o)(5)(C)) (40 CFR § 80.1428(c)).

[3] The green/blue lines are equal to the top of the bar for all years except 2014 and red for all years.

Finally, EISA requires that the regulations include a provision which allows an obligated party that is unable to generate or purchase a sufficient number of credits to carry a deficit to the following calendar year, so long as the obligated party meets the biofuel requirements the following year and generates or purchases sufficient credits to offset the deficit from the previous year (42 USCS § 7545 (o)(5)(D)).

2.2.3.1 RIN Market

In furtherance of EISA credit requirements, the EPA has promulgated regulations for creating RINs, which are generated to represent a quantity of biofuels that has been produced or imported in ethanol equivalents (40 CFR § 80.1425) (40 CFR § 80.1426). Figure 2.4 illustrates the routes for RIN creation, separation, and other actions. Table 2.1 summarizes the number of RINs generated for fuels as determined by the EPA.

RINs are only generated by biofuel producers and importers when the fuel is designated and intended for use as transportation fuel, heating oil, or jet fuel and meets the other requirements specified in 40 CFR §80.1426 (40 CFR § 80.1426(c)). RINs can be separated from volumes of renewable fuel, and any person registered with the EPA pursuant to 40 CFR §80.1450 can own the separated RIN and transfer it an unlimited number of times during the year in which it was created (40 CFR § 80.1428(b)). However, only obligated parties can bank RINs for compliance during the year following the RIN's creation.

An obligated party then can demonstrate compliance by "retiring" a sufficient amount of RINs to meet RVOs using the formulas specified for each fuel type in 40 CFR § 80.1427 (40 CFR § 80.1427). In addition, at the end of each year, obligated parties and biofuel exporters must submit an annual compliance report to the EPA that specifies, among other things, the RVO for the party, any deficit carried over by the party from the previous year or carried into the subsequent year, and information related to the RINs and cellulosic biofuel (D3) waiver credits used for compliance (40 CFR § 80.1451(a)).

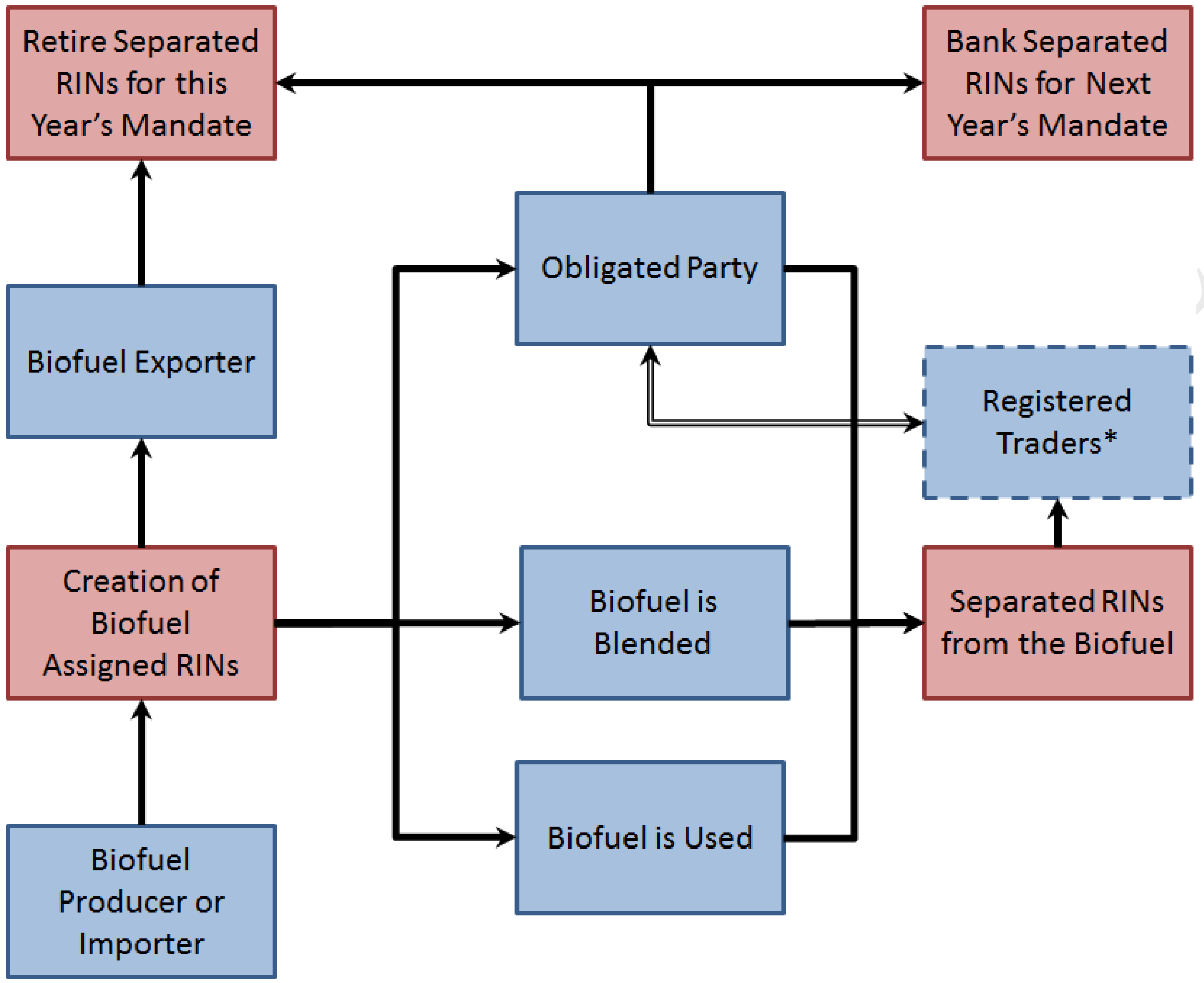

Figure 2.4. Process flow-diagram for creation, separation, transfer, retirement, and banking of RINs.

*The dotted line box for traders indicates the system boundaries are larger than shown. That is, a trader is anyone registered with the EPA for handling RINs which can include market participants already shown in other blue boxes.

Table 2.1. RIN Equivalence Values (EV) for Biofuels (RIN per Gallon of Ethanol-eq) as Assigned by the EPA

Fuel Category	Amount	EV (RIN/gal ethanol-eq. fuel)
Ethanol	1 gal	**1**
Biodiesel	1 gal	**1.5**
Butanol	1 gal	**1.3**
Renewable Diesel	1 gal	**1.7**
Biogas	77,000 Btu (LHV)	**1**
Electricity	22.6 kWh	**1**

Source: 40 CFR § 80.1415(b)

EV = (R/0.972) * (EC/77,000)
Where:
R = Renewable content of fuel.
EC = Energy content of the fuel, in Btu per gallon (lower heating value).

2.2.3.2 RIN Validity

The EPA has promulgated regulations that address when a RIN is deemed invalid as well as the effect of an invalid RIN. RINs are invalid for compliance if they are duplications, based on an incorrect volume of biofuel, expired, do not represent a biofuel, were transferred to multiple parties, or fall under other situations specifically addressed in 40 CFR §80.1431(a) (40 CFR § 80.1431(a)). A party possessing an invalid RIN must retire the RIN, and the RIN cannot be used to meet RVOs, regardless of whether the party had a good faith belief the RIN was valid (discussed in greater detail in Section 4 below) (40 CFR § 80.1431(b)).

If an obligated party has transferred invalid RINs, any valid RINs remaining in the obligated party's possession must be first applied to correct the invalid transfer before the obligated party can meet its own renewable fuel obligation (40 CFR § 80.1431(b)). The EPA does provide one exception in the case of RINs that were improperly generated as a result of a broken meter, inadvertent temperature correction error, or inadvertent administrative error under 40 CFR §80.1431(c), so long as all of the stipulations in that section are met.

2.2.4 Waiver, Exemptions, and Modification of Mandates

EISA provides waiver authority to the EPA, applicable generally as well as specifically to cellulosic biofuel (D3) and biomass-based diesel (D4). In addition, EISA requires a modification to the statutorily defined volumetric mandates when certain waiver thresholds are met.

2.2.4.1 General Waiver

EISA provides the EPA (in consultation with the Secretaries of Agriculture and Energy) the ability to waive renewable fuel (D6) volumetric mandates for a calendar year, in whole or in part (42 USCS § 7545 (o)(7)(A)). A general waiver can take place either after a petition from a state or obligated party or on the EPA's own initiative (42 USCS § 7545 (o)(7)(A)). EISA specifies two sets of criteria under which the Administrator may issue a waiver: (1) The implementation of the RFS for the calendar year would severely harm the economy or environment of a state, region, or the United States, or (2) there is inadequate domestic supply (42 USCS § 7545 (o)(7)(A)). A waiver automatically terminates after one year, but the Administrator may renew the waiver after consultation with the Secretaries of Agriculture and Energy (42 USCS § 7545 (o)(7)(A)).

2.2.4.2 Cellulosic Biofuel Waiver

For cellulosic biofuel (D3), in any calendar year in which the projected volume of production is lower than the volumetric mandate for that year, the EPA (based on an estimate from the EIA) must reduce the applicable volume for the calendar year to the projected volume (42 USCS § 7545 (o)(7)(D)). When the EPA reduces the applicable volume of cellulosic biofuel (D3) for the calendar year, the EPA also has the option to reduce the applicable volume of total renewable fuel (D6) and advanced biofuel (D5) by the same or a lesser volume (42 USCS § 7545 (o)(7)(D)).

In addition, whenever the EPA reduces the cellulosic biofuel (D3) volume, the EPA must offer cellulosic biofuel waiver credits (42 USCS § 7545 (o)(7)(D)(ii)) which are priced at the higher of $0.25 per gallon or the amount by which $3.00 per gallon exceeds the average wholesale price of a gallon of gasoline in the United States (42 USCS § 7545 (o)(7)(D)(ii)).

2.2.4.3 Biomass-based Diesel Waiver

The EPA (after consulting with the Secretaries of Agriculture and Energy) must issue a waiver if the EPA determines that there is biofuel feedstock disruption or other market conditions that could increase the prices of biomass-based diesel (D4). The waiver may last for up to 60 days reducing the annual volumetric requirement by no more than 15 percent of the annual volumetric requirement (42 USCS § 7545 (o)(7)(D)(ii)).

The EPA can extend this waiver for an additional 60 days after consulting with the Secretaries of Agriculture and Energy, (42 USCS § 7545 (o)(7)(D)(iii)). EPA also has the option to reduce the applicable volume of total renewable fuel (D6) and advanced biofuel (D5) by the same or a lesser volume when the EPA issues the initial biomass-based diesel (D4) waiver (42 USCS § 7545 (o)(7)(D)(ii)).

2.2.4.4 Modification of Volumetric mandates

EISA requires modifications to future year volumetric mandates when the EPA waives either (1) at least 20 percent of the volumetric requirement for any biofuel category for two consecutive years or (2) at least 50 percent of the volumetric requirement for a single year (42 USCS § 7545 (o)(7)(F)). In these cases, and if the final year of the waiver is at least 2015, the EPA must promulgate a regulation within one year that modifies the future volumetric mandates for the year 2016 and beyond (42 USCS § 7545 (o)(7)(F)(ii)). In determining the volumetric mandates, the EPA must use the same criteria discussed above in Section 2.2 for establishing volumetric mandates for the years beyond those listed in EISA (42 USCS § 7545 (o)(7)(F)(ii)).

2.2.4.5 Small Refinery Exemption

EISA created special exemptions for small refineries (defined in Appendix A). In general, the volumetric mandates listed in EISA did not apply to small refineries until 2011 (42 USCS § 7545 (o)(9)(A)). In addition, EISA required the Secretary of Energy to determine whether compliance with the volumetric mandates would impose a disproportionate economic hardship on small refiners (which allows the EPA to extend the exemption) (42 USCS § 7545 (o)(9)(B)(i)). In a 2011 report, the U.S. Department of Energy (DOE) concluded that 13 of the 18 small refineries analyzed for the study suffered disproportionate economic hardship and recommended those refineries receive an extension of their exemptions (DOE 2011). The EPA extended the small refinery exemption for those 13 refineries for a period of two years based on the DOE's study report and recommendation (EPA 2011d). Small refineries may also petition at any time for an extension of the exemption due to disproportionate economic hardship (42 USCS § 7545 (o)(9)(A)(ii)) (40 CFR §80.1441(e)(2)).

EISA also provided small refineries with the ability to waive the exemption and participate in the RFS program from the outset or at any time during which the exemption still applies (42 USCS § 7545 (o)(9)(C) and (D)) (40 CFR §80.1441(f)).

2.2.5 Ability to Waive into RFS Program

EISA allows Alaska and United States territories to petition for inclusion in the RFS program (42 USCS § 7545 (o)(2)(A)(ii)). The EPA has promulgated regulations under 40 CFR §80.1443 in furtherance of this opt-in provision. To be approved, the petition must be signed by the governor or authorized representative of the territory and received by November 1 for inclusion in the following calendar year (40 CFR §80.1443). Once the EPA approves the state or territory, all gasoline and diesel fuel refiners and importers in the state or territory become obligated parties and all renewable fuel producers are required to generate RINs and generally comply with EPA's regulations in 40 CFR §80.1400 et seq. (40 CFR §80.1443 (e)).

2.3 EPA Regulatory Authority under EISA

This section discusses the EPA's authority under EISA to create regulations for the RFS program. It will begin with a short overview of administrative law and then discuss relevant case law and the opinions of legal scholars. Thus far, only a couple of court cases have become relevant to the EPA's authority under the RFS program.

2.3.1 Administrative Law Overview

As a general principle of administrative law, a federal agency's power is limited to only those expressly conferred by the enabling statute and/or the Constitution. Under the Administrative Procedure Act, a court reviewing the agency's action, finding, or conclusion decides all relevant questions of law, interprets constitutional and statutory provisions, and determines the meaning or applicability of the terms of an agency action (5 USCS § 706). The Administrative Procedure Act requires a reviewing court to hold as unlawful and set aside any agency action, finding, or conclusions that it finds to be:

1. Arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law
2. Contrary to constitutional right, power, privilege, or immunity
3. In excess of statutory jurisdiction, authority, or limitations, or short of statutory right
4. Without observance of procedure required by law
5. Unsupported by substantial evidence in a case where the agency reviewed the action in a hearing and produced a written record
6. Unwarranted by the facts to the extent that the facts are subject to an independent review by the reviewing court (5 USCS § 706(2)).

The standard is narrow and a reviewing court cannot substitute its judgment for that of the agency in determining whether an action is "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law" (U.S. Supreme Court 1983). Rather, the court must consider whether the agency's decision was based on a consideration of the relevant factors and whether the agency has made a clear error in judgment (U.S. Supreme Court 1983). An agency rule may be arbitrary and capricious if "the agency has relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view or the product of agency expertise" (U.S. Supreme Court 1983, p. 43).

Courts use the two-part test in the United States Supreme Court's decision in *Chevron v. Natural Resources Defense Council* in determining the extent of deference an agency receives during judicial review of an its statutory interpretation. First, the court must look to whether Congress has directly spoken on the issue in the statute (U.S. Supreme Court 1984). If the intent of Congress is clear in the statute, the agency must follow the congressional intent (U.S. Supreme Court 1984). Second, if the statute is ambiguous or silent on the issue in the statute, the court looks to whether the agency's interpretation is a "permissible construction of the statute" (U.S. Supreme Court 1984). An agency interpretation is a permissible construction of the statute unless "arbitrary, capricious, or manifestly contrary to the statute" (U.S. Supreme Court 1984).

In addition, the Supreme Court has noted that the degree of deference provided to an agency administering its own statute should be based on its consistency with earlier and later pronouncements, formality in the process used to make the decision, and relative expertise in the area (U.S. Supreme Court 2000).

2.3.2 American Petroleum Institute v. EPA

SEE SECTION 2 PREFACE

► *American Petroleum Institute (API) v. EPA* addressed the EPA's authority under the RFS program. API objected to the EPA's 2012 projection for cellulosic biofuel (D3) and its refusal to reduce the applicable advanced biofuels (D5) volume for 2012 based on the projected shortfall in cellulosic biofuel (D.C. Cir. 2013).

The Court of Appeals for the D.C. Circuit in *API v. EPA* vacated the EPA's 2012 projection of cellulosic biofuel (D3) production because it was based on an "aspirational" technology, forcing methodology that was not consistent with the EIA's estimate (D.C. Cir. 2013). In this instance, the court held that EISA's requirement that the EPA projection be based on the EIA's estimate implicated an "outcome-neutral" methodology. EISA did not give the EPA authority to set cellulosic biofuel levels at a level which promotes growth (D.C. Cir. 2013).

The court upheld the EPA's decision not to reduce advanced biofuel (D5) volumes for 2012. EPA's decision was based on historical data and future production projections on sugarcane ethanol imports and biodiesel production. The court stated that this was a reasoned explanation (i.e., not arbitrary and capricious) despite not providing numerical projections for how advanced biofuels (D5) would make up for the loss in cellulosic biofuel (D3) (D.C. Cir. 2013). Here, the court reasoned that the EPA only needed to provide a "satisfactory explanation for its actions, including a rational connection between the facts found and the choice made" (D.C. Cir. 2013, p. 481).

2.3.3 Monroe Energy, LLC v. EPA

Recently, the United States Court of Appeals for the D.C. Circuit issued a ruling concerning a challenge to the EPA's 2013 Final Rule, wherein the EPA chose not to reduce the applicable volume of advanced biofuel (D5) and renewable fuel (D6) after reducing the cellulosic biofuel (D3) volumetric requirement from 1 billion gallons to less than 14 million gallons. The petitioner, Monroe Energy, LLC, argued that the EPA acted arbitrarily in not lowering the applicable volumes of advanced biofuel (D5) and total renewable fuel (D6) because it created a situation with more biofuel than the economy can absorb because of the blend wall (discussed further in 2.3.4 below) (D.C. Cir. 2014, p. 914).

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In addition, a second petitioner, PBF Holding Company, intervened in the case (also issue in a similar challenge) and argued that the EPA must only consider the projected volumes of advanced biofuel (D5) and renewable fuel (D6) that could be consumed in 2013 when determining whether to lower the volumetric mandates—no other factors, such as carryover of unused 2012 RINs should be considered (D.C. Cir. 2014, p. 916).

In response to the first challenge, the court held that the EPA is not required to consider any specific factors when deciding whether to lower the applicable volume of advanced biofuel (D5) and total renewable fuel (D6) (D.C. Cir. 2014, p. 917). Further, the court stated the EPA did not act arbitrarily because it exercised its authority in a reasonable manner considering the availability of biofuels that would qualify as advanced biofuel (D5) and renewable fuels (D6), the ability of those fuels to be consumed, and the role of 2012 carryover RINs (D.C. Cir. 2014, p. 917).[4] As for the second argument, the court re-affirmed that the EPA has broad discretion in determining when to lower the advanced biofuel (D5) and renewable fuel (D6) volumetric mandates, and is not required to consider or limited to considering any specific factors (D.C. Cir. 2014, p. 916).

2.3.4 The EPA's 2014 Proposed Rule

For the first time, the EPA is proposing to use its general waiver authority to adjust EISA's volumetric mandates for advanced biofuel (D5) and total renewable fuel (D6) in its proposed 2014 Standards for the Renewable Fuel program (EPA 2013b). See also Figure 2.3. The EPA's use of the general waiver authority is predominantly based on the limitations in the volumes of

[4] The EPA's analysis included consideration of the blend wall in making the determination not to lower the volumetric mandates.

ethanol that can be consumed in gasoline given the reduction in gasoline use in the United States and the number of vehicles that can use higher ethanol blends, commonly referred to as the blend wall (EPA 2013b).

The EPA is justifying the use of its general waiver authority under the "inadequate domestic supply" provision of 42 USCS § 7545(o)(7)(A)(ii) (EPA 2013b). The EPA argues that the term "inadequate domestic supply" is ambiguous and should apply to the full range of constraints, including the ability to distribute, blend, dispense, and consume the renewable fuel in addition to the ability to produce or import the renewable fuel (EPA 2013b). This interpretation, the EPA says, is justified through relying on the common meaning of the word "supply" and through a comparison with other provisions within the CAA, and ultimately the provision must be "judged in terms of availability for use by the ultimate consumer, including consideration of the capacity to distribute the product to the ultimate consumer" (EPA 2013b, p. 71756).

SEE SECTION 2 PREFACE

There are differing legal opinions on the validity of the EPA's interpretation of the provision "inadequate domestic supply." On one end, some argue that any challenge to the EPA's interpretation of the provision would be upheld under the two-part test in *Chevron* (mentioned in Section 2.3.1). The term "inadequate domestic supply" is ambiguous, and as such the EPA should receive deferential treatment under part one of the *Chevron* test (Lafferty and McCullough 2014). On the other end, some argue that if Congress wanted the EPA to determine the distribution capacity (i.e., the blend wall), it would have expressly stated so in the statute as it did in the oxygenate requirements waiver provision also found in the CAA (Coppess 2014). The argument relies on the decision in *Whitman v. American Trucking Assn., Inc.,* in which the Supreme Court refused to allow the EPA to consider implementation costs in setting National Ambient Air Quality Standards where not expressly permitted in the CAA (because the CAA often expressly grants the EPA authority to consider implementation costs) (Coppess 2014; U.S. Supreme Court 2001). Similarly here, if Congress wanted the EPA to consider distribution capacity, it would have expressly stated so as it did in the oxygenate requirements waiver, and a court should not find an implicit authorization for the EPA to consider a factor expressly included in another provision of the CAA (Coppess 2014).

2.3.5 Other Legal Opinions Concerning the EPA's Authority under the RFS Program

Because there are many other varying opinions on the scope and extent of the EPA's authority in implementing the RFS program, this section only highlights a few interesting viewpoints. A few examples include:

- The EPA has the authority to issue multiple 60-day extensions under the biomass-based diesel (D4) waiver because 42 USCS § 7545(o)(7)(E)(iii) allows the Administrator to extend the waiver beyond the 60-day period described in 42 USCS § 7545(o)(7)(E)(ii) or "this clause," referencing the extension clause itself (Lafferty and McCullough 2014)
- The EPA is not required under EISA to hold obligated parties strictly liable for invalid RINs when the obligated party did not cause or contribute to the invalidity, and the EPA could change this rule (discussed in greater detail in Section 4) (Coppess 2014)

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- The EPA could expand the term "obligated parties" since EISA only requires the EPA to establish "compliance provisions applicable to refineries, blenders, distributors, and importers, *as appropriate*" (Jaeger and Snyder 2014, p. 27).

2.4 RIN Fraud

Another issue impacting the RFS program is the issue of RIN fraud, including the generation of fraudulent credits, transferring fraudulent credits between non-generators, and the "buyer beware" nature of the EPA's regulatory scheme to regulate and penalize the use of fraudulent RINs. This section briefly discusses major RIN fraud cases, civil cases concerning the purchase and sale of invalid RINs, and the EPA's proposed rule in response to RIN fraud and the purchase and sale of invalid RINs.

2.4.1 Major RIN Fraud Cases

First, the EPA issued a notice of violation (NOV) in November 2011 to companies who retired invalid biomass-based diesel (D4) RINs generated by Clean Green Fuels, LLC. In June 2012, the owner, Rodney R. Haile, was found guilty of generating and selling over 32 million fraudulent RINs ("Civil Enforcement" 2015).

Second, the EPA issued an NOV in February 2012 to Absolute Fuels, LLC for generating over 48 million invalid biomass-based diesel (D4) RINs and transferring the majority of these to third parties. In March 2013, Jeffrey Gunselman, the owner, was found guilty of selling over $40 million in fraudulent RINs ("Civil Enforcement" 2015).

Third, the EPA issued an NOV in April 2012 for Green Diesel, LLC, which was charged with generating more than 60 million invalid biomass-based diesel (D4) RINs without producing any of the corresponding renewable fuel (D6) and then transferring the majority of these fraudulent RINs to third parties ("Civil Enforcement" 2015).

Fourth, in December 2013 the EPA issued an NOV to e-Biofuels, LLC and Imperial Petroleum, Inc. and charged them with generating more than 33.5 million invalid biomass-based diesel (D4) RINs and then transferring the majority of these fraudulent RINs to third parties ("Civil Enforcement" 2015).

SEE SECTION 2 PREFACE ▶

2.4.2 Civil Cases Concerning the Purchase and Sale of Invalid RINs

A number of district court cases have ruled similarly on the liability of third parties selling and purchasing invalid RINs. This section provides a summary of the results of these cases.

First, the "buyer beware" approach used by the EPA to penalize the use of invalid RINs does not apply to a contract between a buyer and seller (Eastern District of Missouri 2012). Rather, liability is determined by the language within the contract and whether a party is in breach of the contract. If a party is required to deliver "marketable and valid RINs" or the contract contains other similar language, the issue rests on the basic four tenants of a contractual breach:

1) Existence of a contract
2) Plaintiff's performance pursuant to contract
3) Defendant's breach of its obligation pursuant to contract

4) Damages suffered by the plaintiff as a result of the defendant's breach (Eastern District of Missouri 2012).

In other words, if the seller of RINs promises to provide marketable and valid RINs, but instead provides fraudulent or otherwise invalid RINs, the purchaser may collect damages from the seller. One court has held that the damages can include a *pro rata* share of the EPA fines assessed against the purchaser for using the invalid RINs to comply with the RFS2 program (Southern District of Florida 2012).

Second, courts have ruled in numerous states that RINs are not "goods" under the Uniform Commercial Code (UCC) and as such, no express or implied warranties are passed when RINs are sold on the open market (Eastern District of Missouri 2012; Southern District of Florida 2012; District of Kansas 2012). For example, if the contract for the sale of RINs does not include language stating the RINs as marketable or valid (or similar language), no warranty about their validity can be inferred from the sale of the RINs. The courts reasoned that RINs are not considered goods (and thus not subject to the UCC warranty provisions) because RINs can be separated from the tangible fuel they represent and cannot be physically delivered like a good (Eastern District of Missouri 2012).

Third, a court has affirmed that a party is obligated to correct the transfer of invalid RINs under 40 CFR §80.1131(b)(3) only when that party attempts to apply valid RINs towards its own volume obligation (Southern District of New York 2013). 40 CFR § 80.1131(b)(3) states, "[a]ny valid RINs remaining after deleting invalid RINs must first be applied to correct the transfer of invalid RINs to another party before applying the valid RINs to meet the party's Renewable Volume Obligation at the end of the compliance year." The EPA has stated that it will look to the generator or seller of the invalid RINs for relief before turning to the obligated party that retires the RINs, but only where the seller or generator uses valid RINs for its own compliance does 40 CFR §80.1131(b)(3) apply.

2.4.3 EPA Proposed Quality Assurance Program

As a result of the RIN fraud and "buyer beware" nature of the EPA's penalty enforcement, it has proposed a rule which would establish a Voluntary Quality Assurance Program (QAP) to verify the validity of RINs (40 CFR § 80.12158). The QAP would allow for independent third parties to audit the production of biofuel and the generation of RINs (40 CFR § 80.12158). Thereafter, parties could assert an affirmative defense to civil liability for transferring and using an invalid RIN (40 CFR § 80.12164). The affirmative defense would require the party to not have known or have reason to know the RIN was invalidly generated before the RIN was verified (40 CFR § 80.12169). Other provisions in the proposed rule specify how verified RINs that are invalidly generated are to be replaced (40 CFR § 80.12164).

The EPA has proposed two options for the QAP: Option A would require third party auditors to be responsible for replacing invalidly generated RINs and would generally include more strict and detailed requirements, including ongoing monitoring (40 CFR § 80.12169). Option B would assign RIN replacement responsibility to obligated parties and generally include less strict and detailed requirements (40 CFR § 80.12169). The EPA hopes the QAP would improve RIN market liquidity and efficiency and assist smaller renewable fuel producers in selling their RINs (40 CFR § 80.12160).

SEE SECTION 2 PREFACE ►

2.5 Proposed Legislation Amending the RFS Program

This section briefly highlights some of the Congressional bills that have been proposed to amend or repeal the RFS program. To date, none of these bills has been voted on and some of these bills have not been acted upon for over a year. Section 2.5 uses the language on content of the proposed bills themselves and may not be perfectly clear or aligned with existing statutes and regulations described in previous sections.

2.5.1 Bills to Amend the RFS as a Result of API v. EPA

A couple of bills have seemingly aimed directly at the holding in *API v. EPA*. For example, 113 S. 251 (113th Congress) adds a provision on the process by which the EIA estimates cellulosic biofuel (D3) projections and would require the EPA to use the exact estimate from the EIA in setting cellulosic biofuel (D3) levels. In addition, this bill would require the EPA to reduce the volume of renewable fuel (D6) and advanced biofuel (D5) by the same volume as it reduced cellulosic biofuel, eliminating EPA discretion in this decision. A second bill, 2013 H.R. 796 (113th Congress) proposes that, in addition to the above mentioned changes, the projection for cellulosic biofuel for a calendar year cannot be more than five percent or one million gallons (whichever is greater) than the total volume of cellulosic biofuel (D3) that was commercially available in the most recent year for which such data is known.

2.5.2 Bill to Amend the RFS to Limit the Volumetric mandates of Renewable Fuel

A second line of bills aims to limit the volumetric mandates for renewable fuel (D6). For example, 2013 H.R. 1462 (113th Congress) proposed to prohibit the EPA from approving the introduction of gasoline that contains greater than 10-volume-percent (E10) into commerce. 2013 H.R. 1462 is very comprehensive and proposes to reduce previously set volumetric mandates, change waiver requirements, and change cellulosic biofuel (D3) projections, in addition to the E10 limit.

A second bill, 2013 H.R. 1469 (113th Congress) also proposes an E10 limit, but in addition requires that volumetric mandates for renewable fuel be left at existing levels and that all subsequent years listed in EISA be replaced with 7.5 billion gallons, which is about half of current levels. Moreover, the bill strikes provisions to allow for RIN credits for additional renewable fuel produced and strikes language allowing for waivers and modification to the volumetric mandates for all types of renewable fuel.

2.5.3 Bills to Repeal or Phase Out the RFS Program

Finally, a third line of bills seeks to terminate or phase out the RFS program altogether. The U.S. House of Representatives has proposed many bills similar to 113 H.R. 3895 (113th Congress) to terminate the RFS program immediately. However, more recently, 113 S. 2170 (113th Congress) and its companion bill 113 HR 4286 (113th Congress) propose to phase out the RFS program entirely by the end of 2018. 113 S. 2170 and its companion bill propose to reduce the RFS by 20 percent per year through 2018, after which the RFS program would terminate on December 31, 2018.

SEE SECTION 2 PREFACE ►

Section 3. Historical Data and RIN Market Context

3.1 Overview

Section 3 provides historic data and context on the RIN market, which includes related biofuel policies, biofuel feedstocks, biofuel production, and petroleum fuels. Understanding the major historic drivers of the RIN market requires an understanding of the historic context in which the RIN market has operated and how that context has changed over time. For example, biofuel markets have been shown to play a role in the dynamics of the RIN market (Wescott and McPhail 2013; Thompson et al. 2012). Historic and current events such as RFS2 rulemaking and changes to biofuel tax policy could also contribute to major changes in the market (Irwin 2014a). Historically, a contextual understanding of RIN markets was especially important because past participants likely incorporated that information into their own decision making (Irwin and Good 2013f).

Contextual data are referred to and analyzed in Sections 4 and 5 of this report. Section 3 documents contextual data collection, describes major trends, and where relevant, explains interrelated trends seen in multiple data sets. For example, the relationship between biofuel feedstock prices and biofuel prices is highlighted in Section 3, but any potential relationships between those prices and RIN prices are discussed in Sections 4 and 5.

3.2 Petroleum Fuel Markets

Section 3.2 documents data on petroleum fuel production, imports and exports, and prices. Petroleum fuel data are important as they relate to the reference system replaced by biofuels. The RFS2 standards the EPA creates annually are in part based on expected petroleum production levels. Petroleum fuels are also a major input into biofuel systems.

3.2.1 Gasoline and Diesel Production and Net Imports

Figure 3.1 shows monthly gasoline and diesel production from 2009-2014 taken from the EIA (EIA 2014f). Over the last five years, monthly diesel production has increased by ~15%. Diesel production shows seasonal oscillations, with generally low production at the beginning of the year and high production at the end of the year. Monthly gasoline production has decreased by ~40% over five years, and gasoline seasonal oscillations were similar, if less pronounced, than diesel.

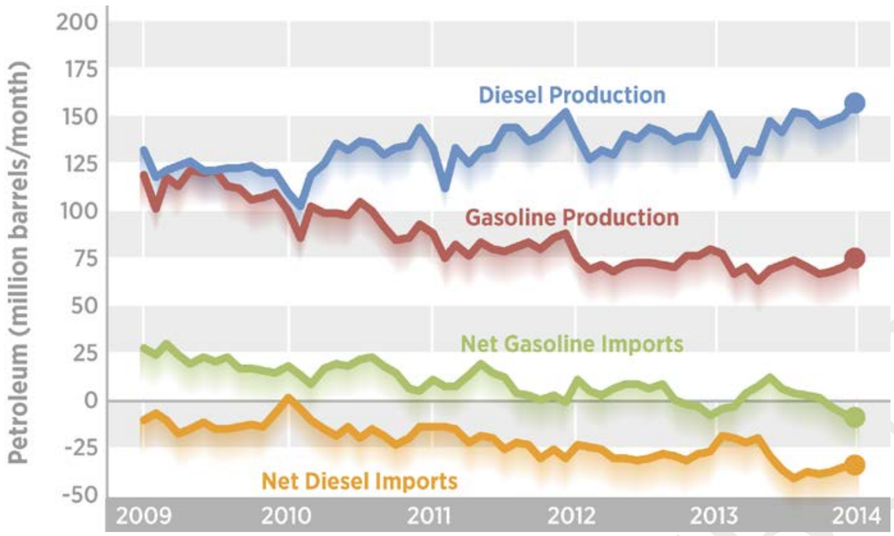


Figure 3.1. Monthly domestic U.S. gasoline and diesel production (million barrels per month) from 2009 - 2014

Source: EIA (2014f)

3.2.2. Gasoline and Diesel Imports and Exports

Figure 3.2 shows monthly net gasoline and diesel imports from 2009-2014 (EIA 2014b; EIA 2014b). Figure 3.2's Frames A and B show a further breakdown of net gasoline and diesel imports into imports and exports (EIA 2014b; EIA 2014c). Diesel and gasoline imports are decreasing, and exports are increasing resulting in decreasing net imports; in fact, over 2009-2014, net gasoline imports decreased by almost 100% and net diesel exports nearly tripled. On net, the United States has been exporting diesel and, over the last couple years (2012-2014), the same has been true for gasoline in some months.

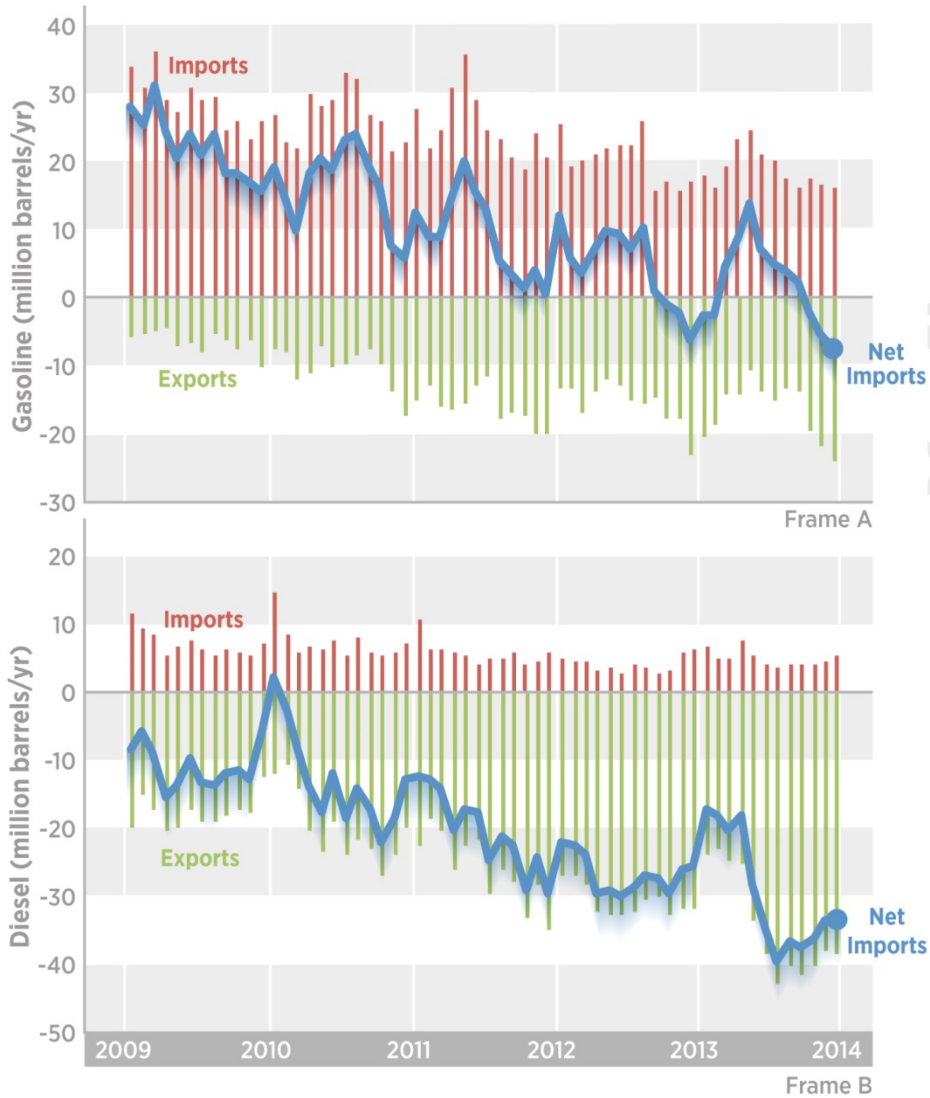


Figure 3.2. Monthly gasoline (Frame A) and diesel (Frame B) imports, exports, and net imports (million barrels per year) from 2009 - 2014

Sources: EIA (2014b); EIA (2014c)

3.2.3. Crude Oil, Gasoline, and Diesel Prices

Figure 3.3 shows monthly crude oil, diesel, and gasoline spot prices from 2009-2014 as taken from the EIA (EIA 2014g). Trends in spot prices across raw crude oil and the fuels produced from crude oil are generally similar. Prices increased from 2009 to early 2011 by ~100-300%; after early 2011, prices leveled off with annual oscillations throughout the year.

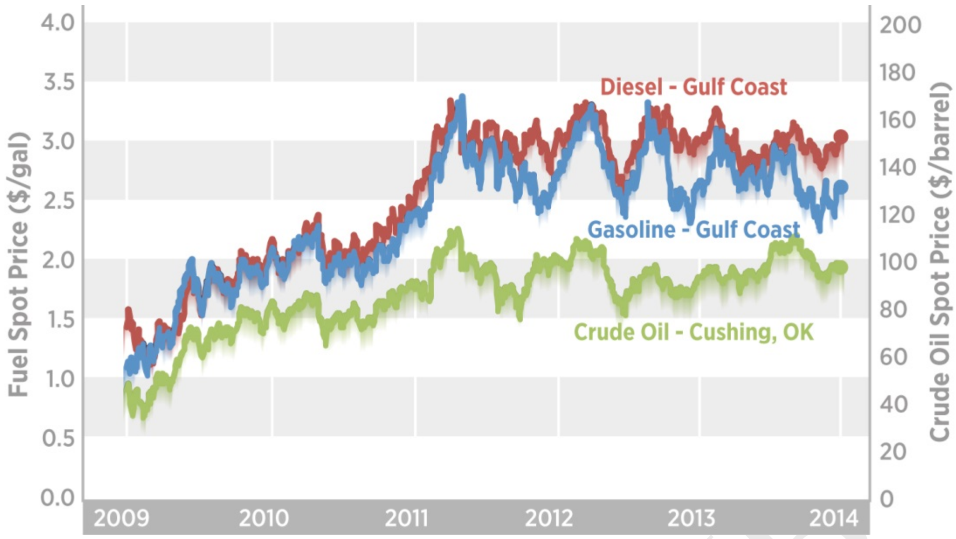


Figure 3.3. Monthly nominal gasoline, diesel, and crude oil spot prices ($ per gallon of fuel or $ per barrel of crude oil) from 2009-2014

Source: EIA (2014g)

Gasoline and diesel reported in $/gal. Crude oil reported in $/barrel.

3.3 Corn and Soybean Markets

Section 3.3 documents biomass feedstock-related production and price data. Biomass feedstocks used domestically for biofuel production mainly include corn and soybeans for renewable fuel (D6) and biomass-based diesel (D4) fuel categories, respectively. Systematic historic price and production levels for other domestic biofuel feedstocks are generally unavailable. Sugarcane is a relevant feedstock for advanced biofuel (D5) production; sugarcane is mostly grown outside of the United States and imported as ethanol, such as from Brazil (Chum et al. 2013). Corn stover and other cellulosic feedstocks used to produce cellulosic biofuel (D3) are other important feedstocks. However, the small size of the cellulosic biofuel market means historic data are also unavailable.

3.3.1 Production

Corn and soybean production data shown in Figure 3.4 are taken from the National Agricultural Statistics Service database (USDA 2014). Corn production decreased from 2009-2012 by ~18%; the largest drop occurred from 2011-2012. Reductions in corn production have been attributed to drought conditions in 2012 and the lower production was expected to have implications for fuel production and RIN generation in 2013 (EIA 2013b). Corn production rebounded to its highest levels in 2013. Soybean production has remained mostly static: from 2009-2013 production has increased by about ~5%.

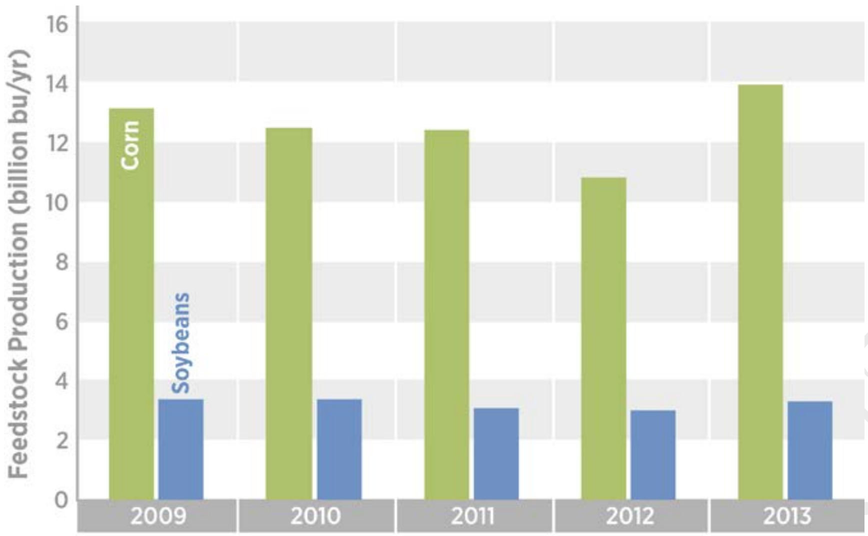


Figure 3.4. Annual corn and soybean production (billions of bushels per year) from 2009-2014

Source: USDA (2014)

3.3.2 Prices

Corn and soybean prices shown in Figure 3.5 were taken from the National Agricultural Statistics Service (NASS) database (USDA 2014). From 2009 to late 2010 these prices were relatively unchanged, but then rose by ~50-60% by mid-2013. By the end of 2013, corn and soybean prices dropped ~30-40% relative to their 2009 levels. The USDA Economic Research Service in 2011 attributes the price spikes, in part, to global adverse weather events reducing crop production (Trostle 2011).

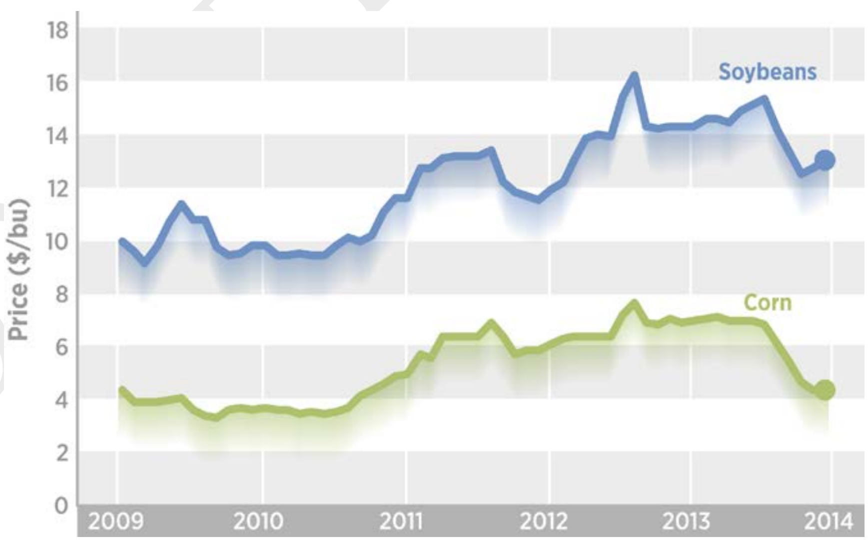


Figure 3.5. Monthly nominal corn and soybean prices ($ per bushel) from 2009-2014

Source: USDA (2014)

3.4 Biofuel Markets

Section 3.4 documents U.S. domestic biofuel production, production capacity, and prices. As noted in Section 3.3, domestic biofuel production to date has primarily involved producing ethanol and biodiesel. The EPA' Moderated Transaction System (EMTS) database notes smaller levels of biomass-based naphtha, non-ester renewable diesel, and heating oil production. Historic production can only be approximately inferred from the EMTS database. Data on international biofuel trading are also included in Section 3.4 and would cover other biofuel systems, such as sugarcane ethanol, that are mainly imports.

3.4.1 Ethanol and Biodiesel Production and Production Capacity

Figure 3.6 shows ethanol and biodiesel production and production capacity data for 2009-2013 from the EIA (RFA 2014; EIA 2014e), which indicate that both production capacities increased during that time period by ~15% and ~25%, respectively. Ethanol production levels remained close to capacity (i.e., ~90-95% of capacity) . Biodiesel production levels had been low (~40% capacity) until major production increases occurred in 2013 to ~90% of capacity.

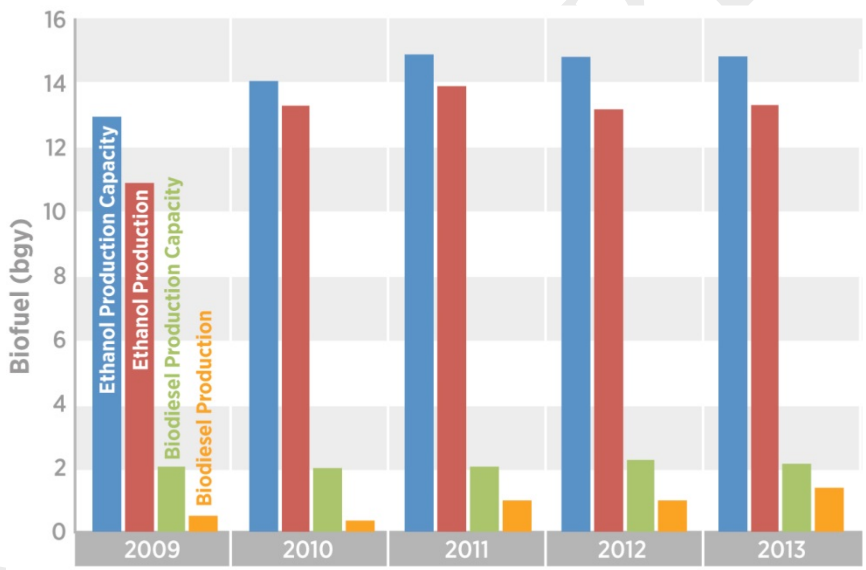


Figure 3.6. Annual ethanol and biodiesel production and production capacity (billion gallons per year) from 2009-2014

Sources: RFS (2014); EIA (2014e)

Figure 3.7 shows inferred production levels for non-ethanol and biodiesel fuels. This figure includes incomplete biofuel production data because it is based on reporting in the EPA's EMTS database. The database does not automatically track small biofuel refineries that have not opted into the RFS. The database also includes biofuel imports. In addition, the database only began collecting data in 2010. The production of fuels shown in Figure 3.7 increased from ~110 millions of gallons per year (mgy) in 2012 to ~450 mgy in 2013. Production increases were mostly in "non-ester renewable diesel"[5], but also in biogas and other biofuels. Most non-ester

[5] That is, renewable diesel that is not from biodiesel

renewable diesel, biogas, naphtha, and renewable heating oil qualified as advanced (D5) or biomass-based diesel (D4) fuels rather than just a renewable fuel (D6) (EPA 2010a; EPA 2011a; EPA 2012a; EPA 2013a).

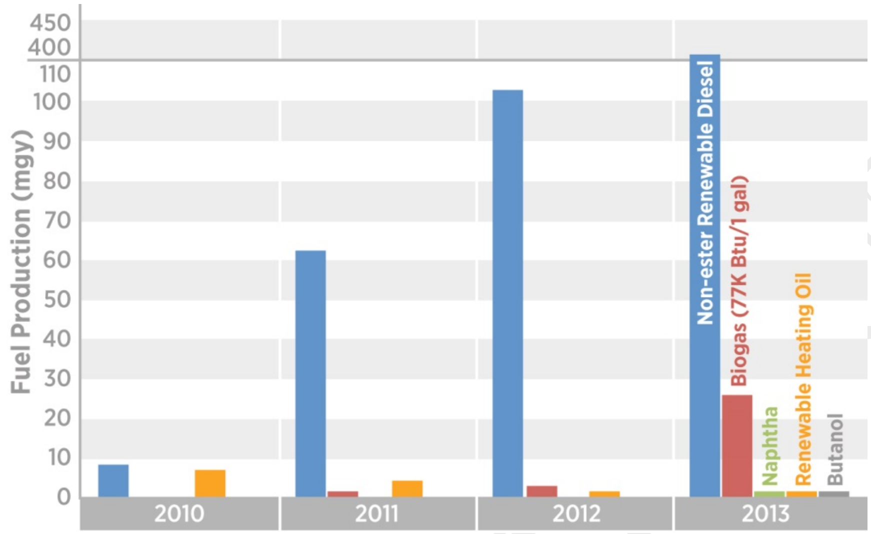


Figure 3.7. Annual production (mgy) of non-ethanol and biodiesel fuels from 2010-2014

Sources: EPA (2010a); EPA (2011a); EPA (2012a); EPA (2013a)

3.4.3 Imports and Exports

Frames A-D in Figure 3.8 show monthly imports, exports, and net imports of the four biofuel categories tracked by the EIA (EIA 2014c; EIA 2014b). Frame A shows exports consisting mostly of corn ethanol and imports consisting mostly of ethanol from sugarcane from Brazil. From 2010-2013, corn ethanol was exported at around a monthly rate of 1 million barrels. Imports of ethanol ranged from ~0-2 million barrels per month. Frames B and C show that imports of biomass-based diesel (D4) and "other renewable diesel" increased to nearly 2 million barrels per month by the end of 2013. Frame D shows that "other renewable fuels" were increasingly being exported at up to ~0.5 million barrels by the end of 2013. The EIA's "other renewable fuels" is a miscellaneous category for other biofuels not captured in other categories such as butanol.

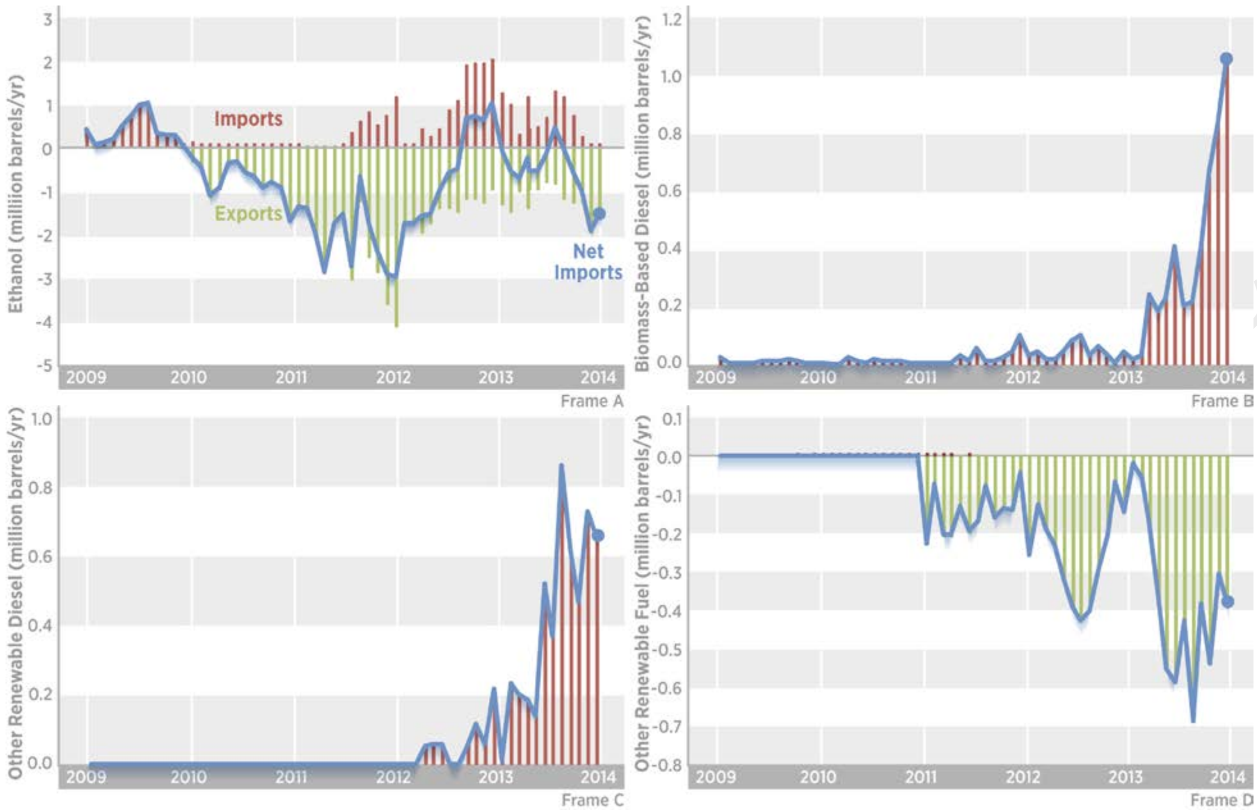


Figure 3.8. Monthly imports, exports, and net imports (million barrels per year) from 2009-2014

Sources: EIA (2014b); EIA (2014c)

(A) ethanol, (B) biomass-based diesel (D4), (C) other renewable diesel, (D) other renewable fuel.

3.4.4 Prices

Monthly average ethanol and biodiesel rack prices for 2009-2013 are shown in Figure 3.9 (Nebraska Energy Office 2014; USDA 2014). A rack price is the wholesale price or the price at which biorefineries sell their fuel. As expected, trends in ethanol and biodiesel average rack prices roughly correspond to trends seen in feedstock prices (see Figure 3.5). Ethanol and biodiesel prices were mostly unchanged until late 2011, when prices increased by about 60% and 80% from 2009 levels, respectively. Initial evidence of fuel price decrease in response to the price decrease in corn and soybean feedstocks may be apparent in late 2013.

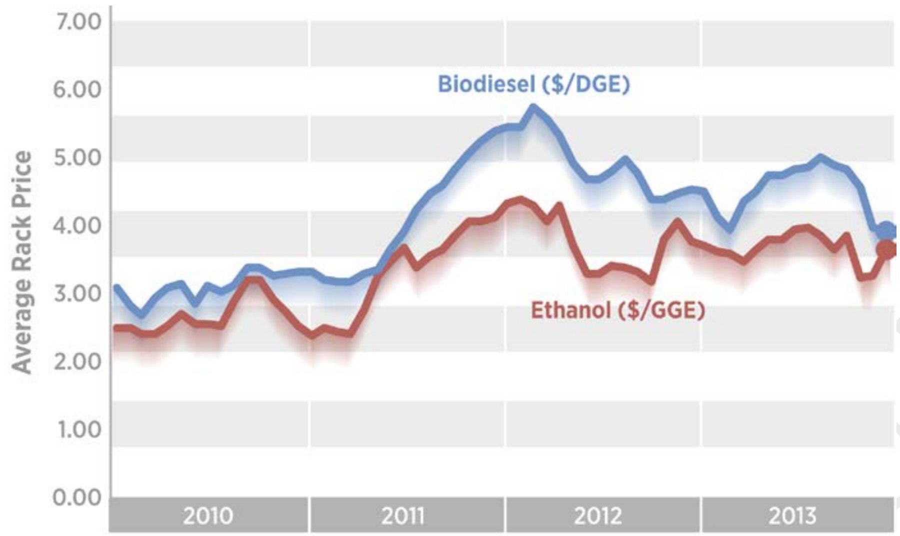


Figure 3.9. Monthly average nominal biofuel rack price ($ per DGE or $ per GGE) from 2009–2013

Sources: Nebraska Energy Office (2014); USDA (2014)

3.5 The RIN Marketplace

Section 3.5 documents and discusses three main data sets on RIN markets. Two accessible data sets for this report are daily RIN market prices and monthly RIN generation. Available RIN data covers the four biofuel categories (five if including the cross-cutting cellulosic diesel [D7]) as defined by the EISA 2007 (see Section 2). A complete RIN trading volume data set covering multiple months or years is not currently publicly available or accessible; links to non-public sources of trading volumes and some example RIN trade volume data are provided in Section 3.5.2 instead.

3.5.1 Generation

Figure 3.10 shows monthly RIN generation by fuel category for 2010-2014. RIN generation has increased among all RIN categories over time by ~20% since 2010 and reflects in part increases in the RFS each year. Most of the growth in RIN generation has been biomass-based diesel (D4). RIN generation for cellulosic biofuel (D3) (and cellulosic diesel [D7]) and advanced biofuel (D5) categories remains a relatively small portion of overall RIN generation.

Renewable fuel (D6), advanced fuel (D5), and biomass-based diesel (D4) RINs are mostly from corn ethanol, sugarcane ethanol, and soybean biodiesel, respectively (EPA 2014d). However, in 2013, ~40% of advanced fuel (D5) RINs came from other fuel systems, specifically biogas (~20%), naphtha (~12%), and non-ester renewable diesel (~8%) (EPA 2013a). In 2013, ~29% of all biomass-based diesel RINs were generated from non-ester renewable diesel. Among biodiesel and non-ester renewable diesel, ~16% of RINs were generated from commercial crop oils besides soy and 33% from waste oils derived from animals and plants (EIA 2014e).

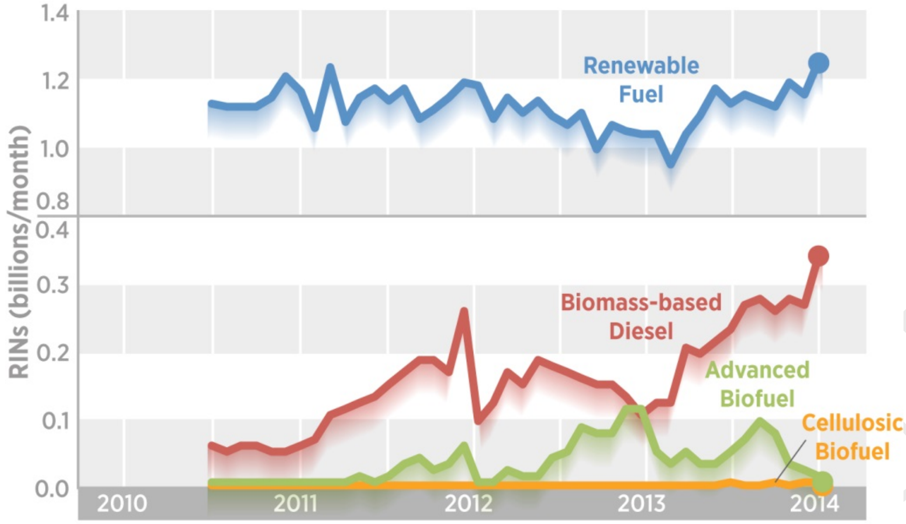


Figure 3.10. RIN generation (billions per month) by fuel category for 2010-2014

Sources: EPA (2010a); EPA (2011a); EPA (2012a); EPA (2013a)

Biofuel categories correspond to EISA 2007 defined categories (U.S. Congress 2007).

Figure 3.11 shows annual RIN generation and the source of those generated RINs for 2010-2014. Most RINs are generated in the United States. However, biofuel importing and foreign company participation in the RFS2 has grown considerably since 2010. Changes in biofuel imports are reflected in biofuel trade data shown in Section 3.4.3. Sugarcane ethanol imports have increased along with importing of "other biomass-based diesel" and "other renewable diesel fuel" (EIA 2014b; EIA 2014c).

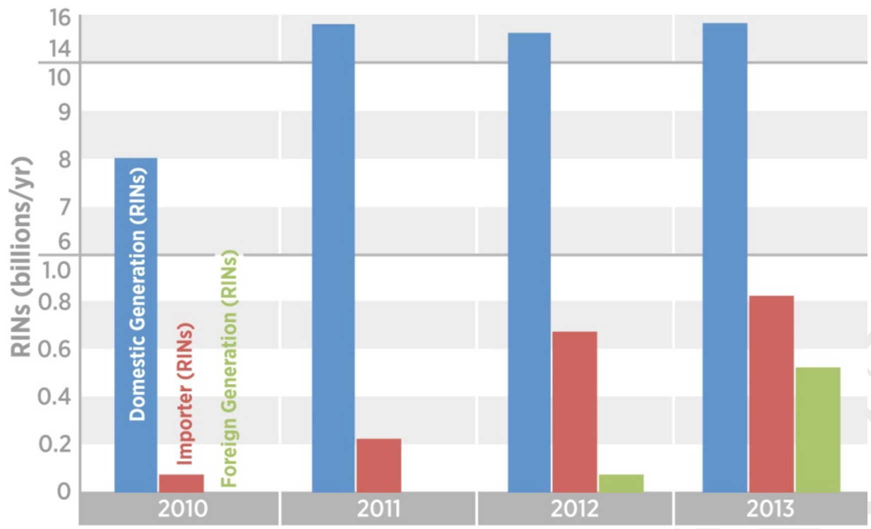


Figure 3.11. RIN generation (billions per year) by the originating source of the RIN from 2010-2014

Sources: EPA (2010a); EPA (2011a); EPA (2012a); EPA (2013b)

3.5.2 Trade Volume

The market for RIN trading is potentially large, with the production of billions of RINs each month (see Figure 3.10); the volume of RIN trading is unclear due to the lack of publicly available data. The EPA publicly reports total RINs registered by month as well other metrics on its website (http://www.epa.gov/otaq/fuels/renewablefuels/epamts.htm), but it does not represent the full extent of data available within the EMTS database. The EMTS tracks individual trades and therefore contains information that would accommodate an understanding of trade volumes. However, because the database contains sensitive business data, the EPA does not publicly report these transactions, and publicly available data from other sources are similarly limited (Yacobucci 2013).

Resources that provide an indirect indication of typical trade volumes include Informa Economics, which completed market research and held conversations with industry participants concerning the number of ethanol RINs flowing into the RIN trading market. Informa Economics estimates that 70-85% of the RINs attached to ethanol used in the supply chain are directly "separated" or directly transferred to obligated parties based on arrangements with blenders and don't reach the trading market (Informa Economics 2013). Another example provided by Argus showed that about 12,000 RINs across biofuel categories were traded on April 12th, 2013 (Argus Media 2013). Over a billion RINs are generated each month (see Figure 3.10). If Argus Media provided a representative data point, the Argus example would also indicate low trading volumes relative to overall RIN production.

3.5.3 Prices

The RIN market is not an open, regulated market (e.g., by the Securities and Exchange Commission). The main repositories of historic RIN market prices are non-public financial databases available from companies such as OPIS, Argus Media, and Platts (Yacobucci 2013). These companies provide market and price assessments based on data they purchase or receive through information sharing arrangements with RIN market participants. The market assessments produced by these companies include price and trade information from their databases (such as Gentile et al. [2013] and Argus Media [2013]). The EPA has only recently been requiring the submission of RIN price data in the EMTS system, but there are no plans for it to become publicly available (EPA 2014d).

Figure 3.12 shows RIN price data obtained from OPIS ("RIN Market Prices" 2014) for cellulosic biofuel (D3), biomass-based diesel (D4), advanced biofuel (D5), and renewable fuel (D6) categories.[6] Over the last five years, RIN market prices have generally been volatile, at least relative to other bioenergy market prices such as biofuels. Reported prices are more reflective of the price for separated RINs. These prices may overstate the average RIN price as many RINs are acquired attached to renewable fuels (Informa Economics 2013).

Table 3.1 shows available public data on cellulosic waiver credit prices and how many waiver credits were purchased (EPA 2014d; EPA 2010b; EPA 2011b; EPA 2012 b; EPA 2013c). Waiver credit price data had not been reported by the EPA for 2012-2013 at the time of writing. Table 3.1 shows that RFS requirements increased in 2012-2013, but potential additional revenue is offset by the lower waiver credit price.

Cellulosic RIN prices shown in Figure 3.12 have not been influenced, at least since 2011, by dynamics within the RIN market itself. For an obligated party, the cellulosic waiver credits (see 2.2.4.2) offered by the EPA are nearly interchangeable for demonstrating compliance with RFS2. A cellulosic waiver credit and an advanced biofuel RIN can be used to demonstrate the same compliance as just cellulosic biofuel RIN. Therefore, since 2011 the price of the cellulosic biofuel RIN has been set mostly by the price of waiver credits with a mark-up based on advanced biofuel prices.

[6] OPIS prices may differ slightly from other sources of price data such as Argus Media and Platts since each financial data source does not capture one RIN trade and their sampling methods may differ.

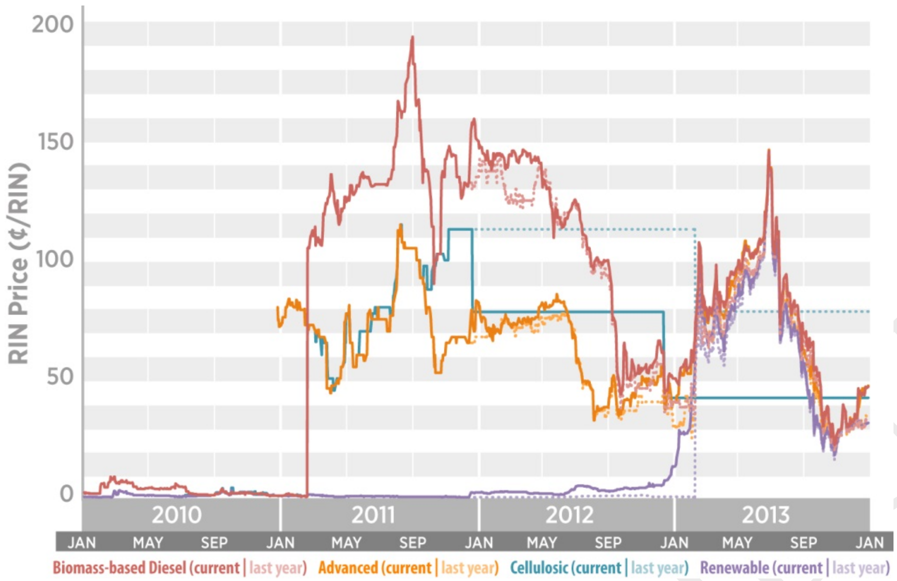


Figure 3.12. Daily RIN prices (¢ per RIN) from 2010-2014

Includes prices for a current RIN and banked RINs from the prior year ("RIN Market Prices" 2014). Fuel categories correspond to EISA 2007 defined categories (U.S. Congress 2007).

Table 3.1. Cellulosic Waiver Credit Prices ($ per Credit), Purchases (Credits per year), and Estimated Revenue ($ per year)

RIN Year	Price	Number of Waiver Credits Purchased	Estimated Revenue Generated
2010	$1.56	12,186	$19,010
2011	$1.13	4,248,388	$4,800,678
2012	$0.78	Unavailable	Unavailable
2013	$0.42	Unavailable	Unavailable

Sources: EPA (2014d); EPA (2010b); EPA (2011b); EPA (2012b); EPA (2013b)

Figure 3.12 generally shows that RIN prices from the preceding year for fuel categories except cellulosic biofuels (D3) track current year RINs, but at a slight discount. This trend is expected given that last year's RINs will expire at the end of the current year.

Non-cellulosic biofuel RIN market prices have undergone at least three distinct shifts in price trends. Before 2011, the RIN market only included RINs for renewable fuel (D6) due to transitioning from RFS1 to RFS2 policies. From early 2011 to early 2013 each RIN category generally followed different price trajectories. Different price trajectories in part reflect differing market conditions for biofuels and the petroleum fuels they replace. See Section 4 for more details. However, in February/March 2013, the RIN market prices converged.

Convergence occurs because less inclusive RIN categories (e.g., biomass-based diesel [D4]) can satisfy requirements for the most inclusive biofuel category (e.g., renewable fuel [D6]). The price increase of the most inclusive renewable fuel category forces price convergence as they are priced similar to or higher than the least inclusive biomass-based diesel fuel category. The price convergence is a natural result of the nested structure of RIN biofuel categories (see Figure 2.1) and would be expected when the price of the most inclusive RIN (e.g., renewable fuel [D6]) biofuel category is similar to the least inclusive RIN biofuel category (e.g., biomass-based diesel [D4]).

3.6 Policy Changes Potentially Effecting RINs

The annual RFS2 rulemaking process and any related policy changes or notable policy or economic related events could influence the RIN market. Over the last few years, several policy-related changes have also occurred that could influence the RIN market, such as leaked RFS2 proposals and changes in subsidies for biofuel production and biofuel import tariffs (Irwin 2014a; Irwin 2013a).

Figure 3.13 plots some prominent key events onto current RIN price data. Major events include the EPA's proposed and final RFS2 rules, EPA's NOVs for companies producing fraudulent RINs, and changes to biofuel tax credits. Biofuel tax credits have been shown to influence RIN market prices (Irwin 2014a).

Additional details on biofuel tax credits and tariff policies are listed in Table 3.2, which describes qualifying fuels, who qualifies, and the tax credits/tariffs. All biofuel tax credits and tariffs originally lapsed at the beginning of 2012. However, the second generation, biodiesel, and alternative fuel tax credits were extended for another two years later in 2013. Lapsed biofuel taxes credits and tariffs were retroactively reinstated (Irwin 2013a). All biofuel tax credits and import tariffs expired at the beginning of 2014.

Figure 3.13 does not clearly show whether any particular event(s) was related to changes in RIN prices. However, several key events clearly preceded major shifts in RIN market prices. These events warranted further investigation in the literature review (Section 4) and analysis sections (Section 5) of this report. A prominent example is the planned soft 2012 RFS2 compliance deadline on February 28th, 2013. The major RIN price increase just prior to the deadline could be related to the end-of-year efforts by obligated parties to comply with the RFS2 through purchasing of RINs.

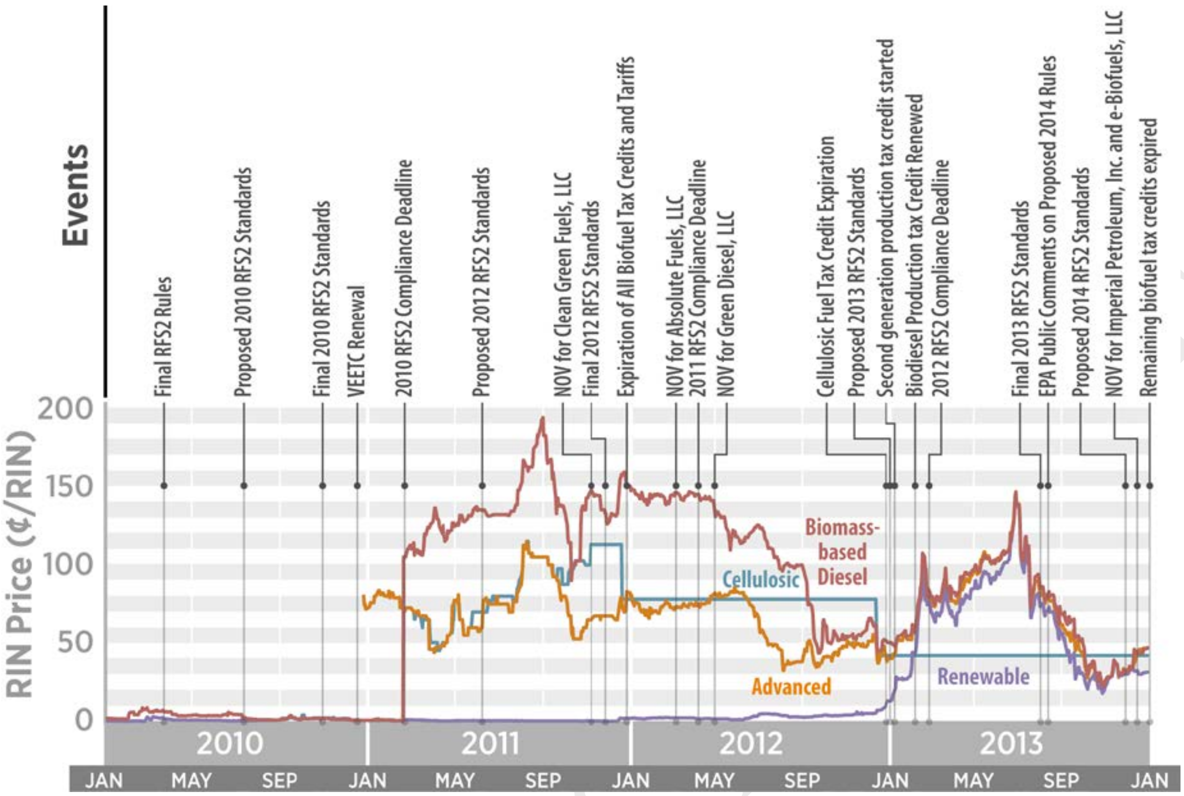


Figure 3.13. Daily nominal RIN prices (¢ per RIN) from 2010-2014

Biofuel categories correspond to EISA 2007-defined categories (U.S. Congress 2007). The timeline indicates important events potentially related directly (i.e., RFS2 rulemaking) and indirectly (i.e., production tax credits [PTCs]) to the RIN market (EPA 2014b; DOE 2014; EPA 2014a).

Table 3.2 Biofuel Tax Credit ($ per gallon) and Tariff Policies from 2009-2014

Biofuel PTCs and Tariffs	Who Qualifies	Qualifying Fuels	Expiration	Tax Credit [$/gal of fuel]
Biodiesel Income Tax Credit	Consumer of the pure fuel	Biodiesel or renewable diesel	Jan. 2014	1.00
Biodiesel Mixture Excise Tax Credit	Blender of fuel	Biodiesel or renewable diesel	Jan. 2014	1.00
Second Generation (i.e., cellulosic) Producer Tax Credit*	Producer of fuel	Ethanol Non-ethanol alcohol Other fuel	Jan. 2014	0.46 0.41 1.01
Volumetric Ethanol Excise Tax Credit (VEETC)	Blender of fuel	Ethanol	Jan. 2012	0.45
Import Duty for Fuel Ethanol	Importer of fuel	Ethanol	Jan. 2012	0.54
Alternative Fuel Mixture Excise Tax Credit	Direct user of fuel	Biogas (and other non-biomass-based fuels)	Jan. 2014	0.50
Alternative Fuel Excise Tax Credit	Blender of fuel	Biogas (and other non-biomass-based fuels)	Jan. 2014	0.50
Small Ethanol Producer Tax Credit	Small ethanol producer (<60 mil gal/yr)	First 15 mil gal ethanol/yr	Jan. 2012	0.10
Small Agri-Biodiesel Producer Tax Credit	Small biodiesel producer (<60 mil gal/yr)	First 15 mil gal biodiesel/yr	Jan. 2012	0.10

*formerly the Cellulosic Fuel Tax Credit

Source: DOE (2014)

Section 4. Historic Drivers on and from the RIN Market

4.1 Overview

Section 4 summarizes, from literature, key research topic areas, major observations and analysis of the historic drivers of the RIN market, and hypotheses about RIN market drivers. In total, about 90 reports, journal articles, theses, and other documents were found that examined various aspects of the RIN market.

Collected literature covers a wide array of topics from many academic perspectives, but is limited in its inclusion of the perspectives of many stakeholders and participants in the RIN market. It includes perspectives from the fields of economics, policy, engineering, and finance, but it has mostly been produced by governments, economists working on bioenergy industry issues, and other academics. Only a few reports from other stakeholders in the RIN market were found, such as in the petroleum industry and fuel blenders.

Collected literature covers three broad topic areas:

- The major historic drivers of RIN market prices and some potential future drivers
- Interactions between the RIN market and major participants in the RIN market
- Interactions between the RIN market, the blend wall, and the development of markets for alternative ethanol blends.

4.2 Major Drivers of RIN Prices

Collected literature identifies key historic drivers and potential future drivers of RIN market prices. Section 4.2 summarizes these insights by describing the general drivers of RIN market prices and then discusses the categories of primary drivers as they have varied over time.

The RIN prices of cellulosic biofuel (D3) have historically not been primarily driven by market participants, as noted in Sections 2 and 3. Since 2011, cellulosic biofuel waiver credits offered at prices based on a formula in EISA 2007 (see Section 2.2.4.2) are the driver of the corresponding RIN prices. Cellulosic RIN prices are excluded from discussion in Section 4.2 due to the drivers being known; they are based on the price of cellulosic waiver credits offered plus a mark-up based on advanced biofuel RIN prices. Speculation about the potential drivers of cellulosic biofuel RINs when waiver credits are not available was not covered in the literature found.

4.2.1 General

Literature indicates that RIN prices are generally determined by four drivers (Thompson, Meyer, and Westhoff 2009; Argus Media 2013):

- Biofuel markets as determined by other secondary drivers such as:
    - Biofuel markets in relation to competing petroleum fuels
    - Biomass feedstock production
    - Biofuel demands (e.g., markets for E10, E15 and E85)
    - The ethanol blend wall

- Biofuel mandated volumetric mandates (i.e., EISA 2007) and how the EPA eventually implements those mandates into the annual RFS for obligated parties
- The nested structure of RIN biofuel categories
- Expectations about the above drivers by RIN market participants
- The transaction costs of trading RINs also factor into the RIN price, but are relatively static and consistent across RIN categories compared to other drivers of RIN prices (Thompson, Meyer, and Westhoff 2009).

4.2.1.1 Biofuel Market Drivers

Figure 4.2 shows the willingness to pay (WTP) for the RIN based on classic supply and demand. When demand is above quantity Q*, the price to supply the quantity exceeds what the market is willing to pay. The difference between Supply Price and Demand Price is the WTP. Additionally, any quantity below Q has a market value above the demand price, so the WTP is zero and the mandate is non-binding. When the quantity mandated is above Q, the price to the obligated party to meet the excess demand is the WTP. The RIN value is assessed to the obligated party.

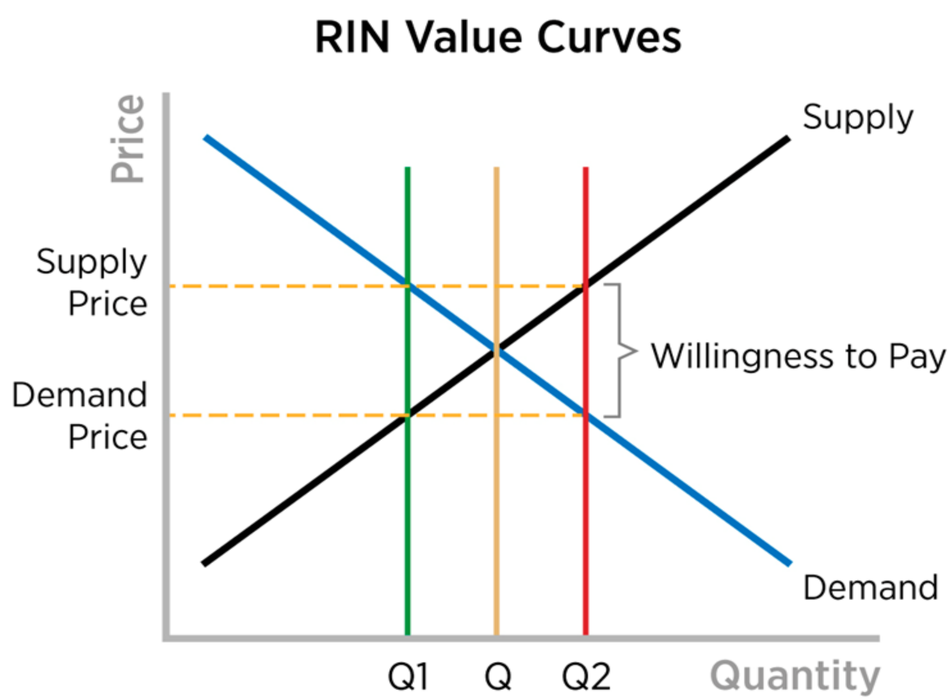


Figure 4.1. Illustration of the supply and demand that determine the Willingness to Pay.

Quantity Q is the break even value. Quantities less than Q the mandates are non-binding, and quantities above Q the mandates are binding.

Therefore, the RIN price is close to $0 when the RFS is non-binding. The RFS would not be binding when obligated parties have other incentives to use biofuels, such as economics (Thompson, Meyer, and Westhoff 2009). Under these circumstances, the RIN's value only consists of the costs of obtaining the RIN and an age value for the RIN (Guidice 2013). These values are unrelated to actual RIN use (Guidice 2013).

Predicting the price of a RIN can be difficult when the mandate is non-binding because the RIN's value will likely be close to zero on an energy-equivalent basis (Guidice 2013). For example, assuming there are no constraints to supplying the biofuels to the market (i.e., the blend wall), RIN market prices would approach $0 if biofuel prices were less than the alternative petroleum fuel. Non-economic incentives for using the biofuel, such as oxygenate mandates prior to EPAct 2005, may also be drivers to use biofuels that keep mandates non-binding.

RIN prices increase when the RFS is binding. A binding RFS forces obligated parties to use more biofuels than they would otherwise use. Obligated parties have the option to use biofuels or buy RINs from the market. Under a binding RFS, RIN market prices increase as the gap increases between obligated parties' WTP for biofuels and the biofuel acquisition price (Thompson, Meyer, and Westhoff 2009; Argus Media 2013). Generally, WTP is equal to the marginal loss of revenue (i.e., biofuel market price minus the competing petroleum fuel market price) plus the cost of acquiring the biofuel. Obligated parties will bid the price of RINs up until it is at least equal to their WTP. However, obligated parties' WTP is not determined in a vacuum and may be influenced by other factors.

The RIN market has many important secondary drivers related to the biofuels and petroleum fuel markets. Drivers influencing the relative prices of biofuel and replaced petroleum fuel, like feedstock prices and the blend wall, can play a role. Changes in relative prices influence how binding the mandate is to obligated parties. Secondary market drivers are discussed more fully in Section 4.3, which addresses the detailed interactions of various actors and other markets with the RIN market.

4.2.1.2 Annual RFS Requirements

EISA 2007 fuel mandates, as well as how these fuel mandates translate into an RFS for determining an obligated party's RVOs, also play a role in RIN market prices. Increases or decreases in the RFS modulate whether a policy is "binding" or "non-binding" for obligated parties. A higher biofuel mandate requires more RINs to demonstrate compliance with the RFS and a lower mandate requires fewer RINs. Increasing mandates can increase RIN prices and relaxing mandates can decrease prices. The extents to which RIN prices increase or decrease in response to changes in the mandate are moderated by the other drivers described in section 4.2.1.

4.2.1.3 The Nested Structure of RIN Biofuel Categories

The nested structure (see Figure 2.1) of RIN categories creates interactions between RIN market prices. The nested structure of RINs allows biomass-based diesel (D4) RINs to satisfy requirements for renewable fuel (D6) and advanced biofuels (D5), and advanced biofuel RINS can also satisfy requirements for renewable fuels.

The nested structure of RINs means that the price of a renewable fuel RIN price will generally act as a price floor for advanced biofuel (D5) or the biomass-based diesel (D4) RINs. An advanced biofuel price RIN will generally act as a price floor for biomass-based diesel RIN price. Figure 3.12, showing historic RIN market price data, supports this assumption through RIN price convergence when renewable fuel RINs increased in 2013.

4.2.1.4 Market Participant Expectations About Price Drivers

Market participant expectations about the above drivers (e.g., the RFS) also drive RIN market prices (Thompson et al. 2012; Lade, Lin, and Smith 2014). For example, expectations about whether the RFS will be binding or waivers will be granted can play a role in RIN market pricing (Thompson, Meyer, and Westhoff 2009). The effect of participant expectations are a logical outgrowth of a market sensitive to EPA rulemaking or other policies and changes in related biofuel markets. Changes to RIN market prices based on participant expectations are not considered "speculation" for the purposes of this report.

Uncertainties in the legislative and regulatory arenas play a role in how market participants price RINs and influence current RIN prices (Westcott and McPhail 2013). The RIN market is a rapidly evolving market with a limited historic context, so participants may currently—and in the future—continue to consider the RIN market highly uncertain when participating individually (Westcott and McPhail 2013; Lade, Lin, and Smith 2014). If market participants are uncertain about how the market could develop, then the RIN market could reflect that uncertainty in increased price volatility. The lack of an open futures market for RINs or for liquid fuels in some regions implies that obligated parties are unable to lock in positions for a long period of time (Figer 2011). Expectations may, therefore, be playing a larger role in variability than they would if there were an open futures market.

The overriding drivers of RIN market prices have, in general, changed at least three times, as described below in subsequent sections and in Figure 4.2. These three notable time periods are post implementation of the RFS2 and pre-2013, in early 2013, and at the end of 2013. A few recent studies also speculate on expected market prices for 2014 based on recent RIN market history.

Speculation here and the rest of this report refers to attempts to manipulate prices. A possible example of speculation would be strategically withholding excess renewable fuel (D6) RINs that cannot be banked in order to drive up the price of other RIN categories for an increased profit from selling those RINs.

Few papers have explicitly looked at "speculation", mostly because it is difficult to evaluate given the lack of transparency of the RIN market and need to have RIN trading volumes in order to study it. The few papers covering speculation concluded that the run-up in RIN market prices may have included unusual speculative buying, but generally the value of renewable fuel (D6) RINs are fundamentally supported by the expected relationship between RIN markets and the ethanol blend wall (Irwin and Good 2013c; McPhail, Westcott, and Lutman 2011; Irwin 2013). RIN market price increases could and likely were collectively predicted by RIN market traders; traders pricing RINs based on their expected values given near market conditions is not unexpected. See Section 4.3.5 for more details.

4.2.2 Major Drivers of RIN Prices Pre-2013

Pre-2013 renewable fuel (D6) RINs (i.e., mostly from corn ethanol) were priced at ~$0/RIN (see Figure 3.12). Low conventional ethanol RIN prices until 2013 suggest a non-binding RFS. The RFS did not force more consumption than obligated parties desired. Factors other than the RFS provided economic incentives for increased ethanol production such as the ethanol price and biofuel blending tax credits (Guidice 2013, McPhail, Westcott, and Lutman 2011; Babcock and

Pouliot 2013b). In 2012 small increases in renewable fuel RIN prices (shown in Figure 3.13) indicate a lightly binding RFS, possibly for only some obligated parties.

Pre-2013, biomass-based diesel (D4) RINs (i.e., mostly from soybean and waste oil biodiesel) and advanced biofuel (D5) RINs (i.e., mostly from sugarcane ethanol) were generally priced at ~\$1.25-\$1.75 /RIN and ~\$0.5-1.00/RIN, respectively (see Figure 3.12). High RIN prices imply binding mandates and a relatively high differential between WTP for the biofuels and petroleum fuel prices (McPhail, Westcott, and Lutman 2011). Lower biodiesel RIN market prices in late 2012 and early 2013 have been linked in part to large increases in biomass-based diesel production. Production increases occurred in anticipation of RINs from biodiesel being used, making up the gap between the renewable fuel volumetric mandates and the blend wall on corn ethanol blending in 2013 (Irwin and Good 2013i).

4.2.3 Major Drivers of Prices in Early 2013

Many studies published prior to 2013 note that biofuel market constraints are expected to eventually limit the ability of obligated parties to meet EISA 2007 renewable fuel (D6) mandates (McPhail, Westcott, and Lutman 2011). If required volumes of renewable fuel exceed the blend wall than either the RFS will need to be lower than the EISA 2007 mandated volumes or RIN prices will increase due to a transition to a binding renewable fuel mandate.

In early 2013, renewable fuel (D6) RIN prices increased to >0.5 (\$/RIN) (see Figure 3.12). The renewable fuel RIN price increase is an indicator that the E10 blend wall was expected to become a major constraint (Irwin and Good 2013h; EIA 2013a). Increases in renewable fuel RIN prices may also imply that market participants do not expect that expanded consumption of higher ethanol blends such as E15 (10.5-15% ethanol) or E85 (51-83% ethanol) will relieve the pressure from the E10 blend wall (Irwin and Good 2013h). To use stored RINs to reduce ethanol blending below 10% of motor fuel use in 2014, let alone future years, is not expected to be possible (Thompson et al. 2012). The rise also may also suggest that market participants are not expecting dramatic EISA 2007 mandate waivers in RFS rules for 2014 (Irwin and Good 2013h). Evidence suggesting this expectation in the RIN market includes the RIN market price decreases that followed EPA comments indicating potential waivers to the EISA 2007 mandate (see Section 4.2.4).

Decreases in banked renewable fuel RINs (see Section 2.2.1) in 2012 may have affected the timing of RIN price increases, but only delayed the inevitable effect of the blend wall (Thompson et al. 2012). A drought in 2012 led to significant increases in corn prices and a slowing in domestic ethanol production and exports and reduced RIN stocks (see data in Sections 3.4 and 3.5) (Paulson 2012b). Finalization of banked RIN totals in late-February 2013 likely accelerated the demand for available renewable fuel (D6) RINs as some obligated parties looked to mitigate expected shortfalls (EIA 2013a; EIA 2013b). In early 2013, corn trends appear to have contributed less to the increasing RIN prices than the blend wall, as corn future prices in early 2013 were declining (Irwin and Good 2013c). 2013 renewable fuel RIN generation implies that stocks of banked RINs were further reduced by the end of 2013 (Paulson 2012b).

Renewable fuel prices increased enough that RIN market prices for renewable fuels, advanced biofuels (D5), and biomass-based diesel (D4) converged. The blend wall limited ethanol use and therefore renewable fuel RIN generation. Limits on renewable fuel RINs led to RIN market price increases. The RIN nested structure led to a coupled biomass-based diesel and renewable fuel price (Irwin and Good 2013e; Irwin 2014a). Biodiesel use is a relatively small component of diesel blends used for vehicles. Biodiesel has room to grow up to a blend of 5% Biodiesel is also considered the same as petroleum diesel, so there are not requirements for infrastructure or vehicles. Overall prices of biomass-based diesel RINs were decreasing in late 2012 and only increased in 2013 with renewable fuel RIN prices.

Increases in U.S. biodiesel production and, as a result, biomass-based diesel RIN generation, are estimated to lead to a surplus of RINs for 2013 (Paulson and Meyer 2013). Increased biodiesel production resulted in a decrease in biodiesel price in the second half of 2013 (Irwin and Good 2013h).

4.2.4 Major Determinants of RIN Prices in Late 2013

Few studies could be found on late-2013 RIN market prices.

In July/August 2013, all RIN prices began decreasing from a high of near \$1.5/RIN to \$0.25-0.5/RIN by the end of the year (see Figure 3.12). By late 2013, advanced fuel and renewable fuel RIN market prices were similar at around \$0.3/RIN. Biomass-based diesel (D4) RINs were priced at ~\$0.45/RIN.

These major price decreases appear to be linked to expectations about the 2014 RFS. For example, the EPA comments on August 6th, 2013 (see Figure 3.13) about the potential for waivers to the mandates in 2014 were followed by a ~25% decrease in RIN prices (Brown 2013; Yeh and Witcover 2014). News about the EPA reducing RFS fuel requirements throughout the fall of 2013, through leaked documents and eventual proposed rules, contributed to further declines in RIN market prices in late 2013 (Irwin 2014a). RIN market prices could also indicate market expectations that the EPA will maintain proposed waivers (see Section 2.2.4) to the advanced biofuel and renewable fuel (D6) mandate (Irwin 2014a; Irwin and Good 2013h; Irwin 2013b). Divergence of biomass-based diesel (D4) and renewable fuel prices indicates that as the renewable fuel RIN price floor dropped, other biofuel market drivers dominated biomass-based diesel prices by the end of 2013.

4.2.5 Predictions for 2014

Based on the events of 2013 and other historic data, there are some predictions for RIN market prices in 2014.

If the proposed RFS for 2014 were finalized, then the renewable fuel (D6) mandates would be non-binding, or at least weakly binding. A non-binding mandate would lead to a renewable fuel RIN price of ~\$0/RIN (Irwin 2013d). Conversely, if the original EISA 2007 mandate becomes the RFS for 2014, then the renewable fuel RIN price will range from ~\$0-1.75/RIN based on expected renewable fuel and petroleum fuel market prices (Irwin 2013c). Renewable fuel RIN prices would be at the lower end of that range if the biodiesel production tax credit is extended, and at the higher end of the range if not extended, due to biodiesel being used to meet renewable fuel RVOs (see Section 4.3.6 for details).

Biomass-based diesel (D4) prices will range from ~\$0.15-0.85 if the EISA 2007 mandate is used in 2014, or ~\$1.1-1.75/RIN if the EISA 2007 mandate is not used (Irwin 2013c). The former range would be driven by biodiesel-related markets and the latter range includes renewable fuel RIN prices. The lower estimate in each range assumes an extension of the biodiesel production tax credit while the higher estimate assumes that it expires. Actual pricing along the above ranges for renewable fuel and biomass-based diesel will depend heavily on market expectations about whether the proposed 2014 RFS will be made final or will be changed.

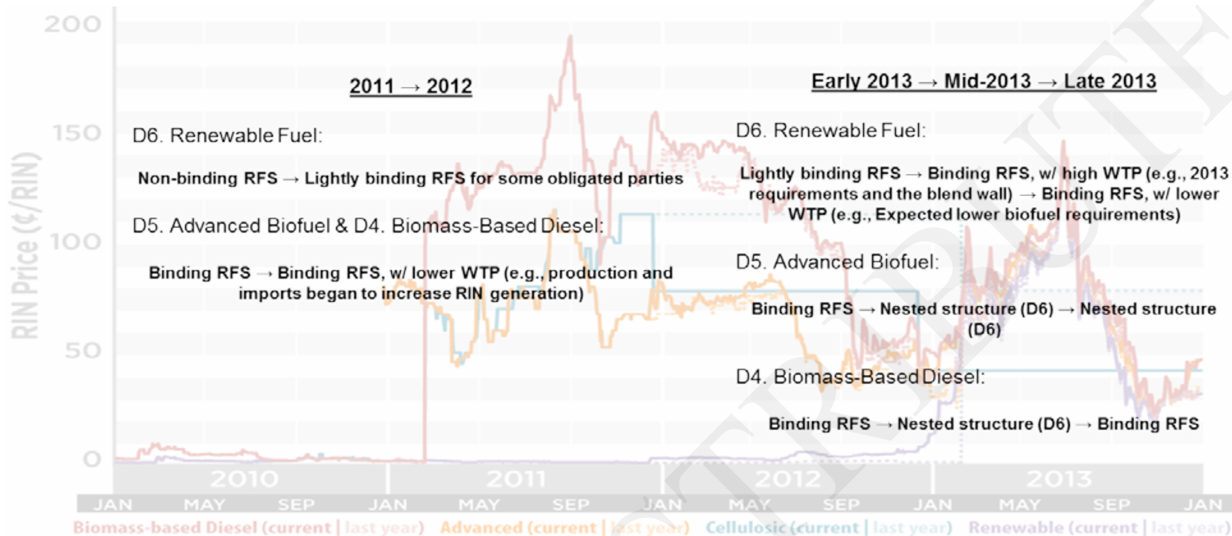


Figure 4.2. Summary of primary RIN market drivers from 2011-2014

4.3 How RIN Market Participants Drive and Can Respond to the RIN Market

Section 4.3 summarizes literature on the interactions between RIN market participants and the RIN market. Section 4.3 includes information on the EPA, obligated parties, blenders (who may also be obligated parties), biofuel producers, and traders of RINs. Section 4.3 ends with economic research on how the RIN market affects the relative "economic welfare" of various industries and geographic regions in the United States.

4.3.1 The EPA

Several papers note the EPA's approach to setting each year's RFS and what non-statutory factors are considered. As described in Section 2, the EPA is required to operate within the constraints of its authority, but it has some discretion in setting the RFS. Exercise of that discretion is in part based on feedback from conditions in the RIN market. The EPA has generally:

- Heavily weighted (see Section 2.3.2) EIA petroleum fuel demand and biofuel production estimates
- Considered an individual year in isolation. For example, last year's production of cellulosic biofuel (D3) is not considered; only the refineries online or planned to come online are considered
- Considered outstanding RIN deficits and the number of potentially banked RINs

- Shown interest in maintaining a stock of banked RINs to maintain flexibility in the RIN market
- Been optimistic regarding potential for 2014 cellulosic biofuel (D3) production, although the EPA can only act on this optimism within the constraints of recent court cases (Massey and Capozzola 2013; Paulson 201b) (see Section 2).

The EPA also has indirect roles in the RIN market that are not discussed in this report. The EPA's role in, for example, approving higher blends or qualifying additional biofuel production processes could influence how the RIN market changes over time (Paulson and Meyer 2012).

The EPA's major role in shaping the RIN market is currently through the proposed waiving of the EISA 2007 mandates for non-cellulosic biofuel categories. The EPA has proposed waiving EISA 2007 advanced biofuel (D5) and renewable fuel (D6) mandates in the 2014 RFS. The potential mandate waiver is controversial, with the bioenergy industry pushing to keep the mandate and the petroleum industry arguing for the waiver (Bryan 2014). Researchers anticipate that the EPA's decision on waivers will have major effects on which industries benefit (e.g., see Section 4.3.6) (Tyner, Taheripour, and Hurt 2012). The potential impacts of waiving or not waiving the mandate are explored in Section 5.

4.3.2 Obligated Parties

Section 4.3.2 examines interactions of obligated parties only within the RIN market. Blending and general RIN trading behavior in which obligated parties may also participate are examined in Sections 4.3.3 and 4.3.5.

Obligated parties are the only RIN market participants allowed to bank RINs. The obligated party RIN banking system allows for flexibility in meeting their RVOs. Obligated parties can bank up to 20% for the total mandate rather than a specific category (Paulson 2012a).

2012 net RIN generation exceeded the renewable fuel mandate, but the 2012 corn drought contributed to a depletion of net banked RINs for the year (Westcott and McPhail 2013). The 2012 RFS was met through the use of both newly generated RINs and depletion of banked RIN stocks.

The situation in 2012 illustrates how the design of the RIN market system can be used by obligated parties to respond to variability in the biofuel market (Paulson 2012d). However, the drawdown of banked RIN stocks, in combination with increased corn prices and the blend wall, was expected to contribute to increases in RIN market prices and market volatility, eventually seen in 2013 (Babcock 2012; Paulson and Meyer 2012).

Bankable RINs were still available to obligated parties at the end of 2013, but the EIA and others expect that the number of banked RINs will continue to fall in 2014 (EIA 2013b). Future conditions in 2014 could result in the drawdown of 25-50% of available renewable fuel (D6) banked RIN stocks (Paulson 2013a). Once banked renewable fuel RIN stocks are depleted, the only other option would be to use biomass-based diesel (D4) or advanced RINs (Paulson 2013a). Biomass-based diesel prices are the backstop prices once renewable fuel RIN stocks are depleted. Expectations about drawing down the stock of banked RINs could be contributing to continued high RIN prices at the end of 2013, despite the EPA potentially waiving part of the EISA 2007 mandate.

The impact of the early 2013 increases in RIN market prices and the implications for prices at the pump, as well as potential responses from the petroleum industry, have been areas of controversy (Schill 2013). Collected literature suggests that in 2013, the impact on prices at the pump has so far been small (at most a few cents) (Irwin and Good 2013e; Pouliot and Babcock 2014; Informa Economics 2013). Figure 3.3 indicates that petroleum fuel prices have oscillated, but remained fairly constant on average. Estimation of the low impact of the RIN market on fuel costs and fuel costs passed on to the consumer likely relates to the low percent of ethanol used in gasoline and the low volume of RIN trading relative to total available RINs (Informa Economics 2013).

A method the petroleum industry might consider to reduce RVOs is to minimize petroleum fuel production and imports (Argus Media 2013; NERA 2012). Restrictions to domestic supply would lead to increased domestic prices of gasoline and ethanol, thus incentivizing domestic fuel sales and/or E85 infrastructure investments. Keeping original EISA mandated fuel volumes will not likely increase the price of gasoline in the long-term (Pouliot and Babcock 2014). Literature indicates clearly that the price impact on supply chain participants is still largely unknown (Irwin and Good 2013b). This topic is covered more thoroughly in the RIN market driver analysis of Section 5.

One hypothetical strategy for obligated parties is to obtain RINs through long-term storage of biofuel. Obligated parties may purchase fuels for their RINs, use the RINs, and store the fuel. There is little examination of these so-called "zombie RINs". However, the high costs associated with storage and other financial considerations imply that a biofuel storage strategy is only an end-of-year compliance strategy and not used in the long-term (Niznik and Kingston 2013). A similar strategy could be maximizing internal use of biofuels by the obligated party to generate more RINs (Argus Media 2013).

Another hypothetical strategy in the financing literature indicates that, under certain circumstances, obligated parties can use RINs as a risk management tool (Ahmedov and Woodard 2012). For example, buying low-priced RINs at 10% of the expected RVO can be used to hedge against the risk of increased RIN prices. However, RINs are not a good risk management tool in the presence of production or blending tax credits because the credits are already mitigating most of the risk of higher RIN prices.

4.3.3 Blenders

Biofuel costs are the predominant factor that sets the RIN market price (see Section 4.2.1.1) and determines when blending will occur, and when RINs are bought by an obligated party (Figer 2011). In general, without tax credits, blenders (i.e., physical blender of biofuels with petroleum fuels) have less incentive to use biofuels, making the mandate more likely to be a significant motivating factor (McPhail, Westcott, and Lutman 2011).

Guidice (2013) indicates that biomass-based diesel (D4), advanced biofuel (D5), and renewable fuel RINs have operated under different market conditions. The strength of the statistical link between underlying blending margins[7] and RIN market prices would therefore vary (Guidice 2013). Regression analysis indicates that the statistical link between blending margin and RIN market prices is significant for biomass-based diesel, less strong for advanced biofuel, and weak for renewable fuel.

The statistical link between blender behavior with regards to renewable fuel (i.e., corn ethanol) and RIN market prices has generally been weak, but the reasons for that weakness have changed over time. Blending margins of renewable fuels have, until recently, been positive, indicating a non-binding mandate for most blenders (Guidice 2013). Until 2013, blending economics, rather than the mandate, continued to drive ethanol use in spite of high corn prices resulting from the 2012 drought. Starting in 2013, blending margins began to be limited by lower petroleum fuel use, the E10 blend wall, and infrastructure limits to E15 and E85 (Westcott and McPhail 2013).

Blenders can increase blending of available biodiesel to generate RINs that could be used by obligated parties to meet mandates for renewable fuel (D6) within the diesel market where biodiesel is not affected by E10 blending limits the way ethanol is affected in the gasoline market (EIA 2013b). The price of biodiesel since the beginning of the year has risen substantially in relation to the price of soybean oil, the main feedstock used to make biodiesel in the United States. In combination with falling soybean oil prices, this has driven biodiesel production profits to levels rarely seen in recent years (Irwin and Good 2013g). The EIA expects higher demand for biomass-based diesel (D4) RINs to impact diesel fuel prices(EIA 2013c).

Blending margins have been negative for biomass-based diesel (D4) and advanced biofuel (D5), thus making those mandates binding (Guidice 2013). However, advanced biofuel and renewable fuels compete for use in E10. The advanced biofuel RIN category has a weaker relationship with the blending margin because the renewable fuel RIN price is a price floor for advanced fuel RIN prices (Guidice 2013). A regression analysis of biomass-based diesel suggests that close to 70% of the price movement in a biomass-based diesel RIN is linked to the blending margin (Guidice 2013).

The California Air Resources Board has implemented the Low Carbon Fuel Standard (LCFS), which rates individual fuels based on their GHG reduction scores and sets a target for the reduction of GHG emissions. The policy requires the fuel to be consumed within California, but the RINs associated with the fuel can still be used to comply with the nationwide RFS2. Renewable fuels can therefore be counted both towards the LCFS and RFS2 as long as the fuel is consumed within the state. For blenders in California, the RIN price has an additive effect under the LCFS. In the long-term, the blending requirements under the LCFS and RFS may differ with requirements from the LCFS increasing versus RFS requirements leveling off or decreasing. LCFS incentives are designed to become stronger in the future (Yeh and Witcover 2014). Blenders interested in minimizing biofuel transportation costs, such as biofuel users in California trying to meet the LCFS, must consider the implications of transporting RIN-attached biofuel in purchasing decisions (Figer 2011).

Under the RFS there is no incentive to further improve the GHG reduction scores once the renewable fuel pathway exceeds the desired mandate. Under the LCFS, in theory, each

[7] This refers to the difference between blending petroleum-based motor fuel and biofuel price.

improvement in the pathway would be accompanied by a larger GHG reduction score, which would increase the value of the fuel. So there is value in being better than the mandates. Policies like LCFS have biofuels in the marketplace compete for GHG emission reduction based on actual GHG emissions.

4.3.4 Biofuel Producers and Importers

Until recently, the renewable fuel (D6) RFS was non-binding because of positive renewable fuel blending margins incentivizing biofuel use. The renewable fuel (D6) is now binding because of the blend wall. Interactions between the corn ethanol market and the RIN market have been minimal relative to interactions between other biofuel markets and the RIN market..

Binding RFS volumetric requirements have led to high advanced biofuel (D5) and biomass-based diesel (D4) and RIN market prices that are expected to increase the profitability of producing and importing those fuels (McPhail, Westcott, and Lutman 2011). Imported sugarcane ethanol is used to meet advanced biofuels (D5) mandates that are not met by domestic biomass-based diesel (D4) (Babcock 2012). Biomass-based diesel can be used for advanced biofuel (D5) and renewable fuel (D6) volumetric requirement if biodiesel supply is greater than biomass-based diesel (D5) RFS volumetric requirements.

Biodiesel production has increased above biomass-based diesel volumetric requirements, to near the estimated industry production capacity, in order to meet the volumetric requirements of other fuel categories (Paulson and Meyer 2013). Commercial domestic production of renewable diesel began in 2013 (see Figures 3.7 and Figure 3.8) and can also be used to bridge the gap between the blend wall and the RFS requirements for renewable fuel (D6). Larger growth in renewable diesel relative to biodiesel in recent years may be related to its greater economies of scale, which are evident in the greater responsiveness of renewable diesel production capacity expansion to prices (Irwin 2013e).

Imported sugarcane ethanol can be used for renewable fuel (D6) RFS volumetric requirements if biomass-based diesel (D4) and advanced biofuel (D5) supply is greater than advanced biofuel (D5) RFS volumetric requirements. A lower advanced biofuel mandate could allow greater possibility for sugarcane ethanol to bridge the gap between the blend wall and the renewable fuel (D6) RFS volumetric requirements (McPhail, Westcott, and Lutman 2011). However, sugarcane ethanol could potentially displace corn ethanol if the blend wall constraints total ethanol use and more important sugarcane ethanol is needed to meet both renewable fuel (D6) and advanced biofuel (D5) RFS volumetric requirements.

Expiration of the tariffs may have contributed to recent corn export to Brazil and sugarcane import to the United States to meet each country’s biofuel mandates. Recently expired ethanol import tariffs made foreign ethanol more expensive, so removal could have theoretically decreased imports. However, projected strong demand for ethanol in Brazil combined with a largely saturated U.S. ethanol market actually meant that elimination of ethanol import tariffs would have almost no impact at least in the short-term (Babcock, Barr, and Carriquiry 2010).

Expectations about PTCs have played a role in RIN pricing (Irwin 2013a). There are direct substitutions between RINs and PTCs: if PTCs incentivize biofuel use to the point that blending margins are positive, then the RFS is non-binding. These policies are competing, not synergistic in their incentivizing effects on the use of biofuels (Babcock 2009). Elimination of the PTC would impact markets modestly, with ethanol production declining (Babcock, Barr, and Carriquiry 2010). However, a PTC expiration would imply that obligated parties' only incentive to invest in infrastructure would be to reduce compliance costs (Babcock 2013). Purchasing RINs or additional use of biofuels is a compliance cost in contrast with tax credits, which are benefits from compliance.

4.3.5 RIN Traders

This section documents RIN market traders' interactions with the RIN market. Traders include obligated parties, blenders, and anyone who meets registration requirements from the EPA to trade RINs. Very little about actual trading practices is known. Examples of RIN trading from Argus Media indicate trading of RINs bundled in the hundreds to thousands with little price variation in a single day (i.e., <5%) (Argus Media 2013). Informa Economics (2013) indicates a relatively small portion of total generated RINs are actually traded.

Based on economic theory and other data sources, the literature collected concludes that traders have been predicting the interactions of policy and markets fairly well (Irwin 2014a). Traders, until recently, traded renewable fuel (D6) RINs at near ~$0/RIN due to the non-binding RFS. Recently, RIN prices have increased as RIN stocks began to be drawn down and expectations about reaching the blend wall increased.

As another example, biomass-based diesel (D4) RIN prices are linked to market expectations and known phenomenon rather than speculation (Irwin 2013a). Traders appear to strongly anchor biomass-based diesel prices to blending margins, but also calibrate prices with consideration of retroactive reinstatement of the blenders' tax credit during periods when the credit has been suspended (Guidice 2013).

RIN traders have had no obvious problems with determining RIN prices through basic methods of anticipating supply and demand, even during large RIN price increases and decreases in 2013 (Irwin 2013b).

4.3.6 Economic Welfare

Several studies included broad evaluation of "economic welfare" transfers between geographic regions, industries, and sectors of the economy. "Economic welfare" in the context of this report refers to the changes in the utility of goods and services for particular groups because of changes in policies. These studies look at broad sectorial and geographic changes rather than specific changes to a particular company or city.

The RIN market itself creates several economic welfare transfers between industrial and societal sectors. RINs increase the price of biofuels sold by producers while obligated parties (i.e., petroleum refiners) pay for the RINs through the price they paid for the biofuel with a RINs or through purchasing RINs on the market that were previously associated with produced biofuel(Figer 2011; Wang et al. 2013; Brown 2013).

RINs benefit the biofuel producers and the benefit might extend to feedstock producers by increasing biofuel producers WTP for biofuel feedstocks. RINs are expected to increase the economic welfare of biomass producers to the extent that increasing the price of biofuels allows biofuel feedstock producers to sell at higher prices due to biofuel producers having a higher WTP for feedstocks (Tyner, Taheripour, and Hurt 2012). The RFS works in the interest of corn and soybean farmers by creating a floor under their commodity prices (Babcock 2009). Economic welfare was simultaneously expected to decrease for other users of biomass feedstocks because of increased prices and/or competition for agricultural resources (e.g., land) (Tyner, Taheripour, and Hurt 2012). The RIN market is expected to lower the economic welfare of food consumers and animal product producers at least to the extent that RINs lead to increases in the prices of feedstocks used for food. Even if the direction is known, the extent of the impacts of the RIN market on biofuel prices are unknown and dependent on interactions between markets in multiple sectors and across geographic boundaries.. For example, the impact of RINs on corn prices would be small if gasoline prices decreased in the future (Meyer and Paulson 2012).

Changes in the economic welfare of U.S. regions are tied to industry locations. Major petroleum-producing or -importing states such as Louisiana, Texas, and California are expected to bear the economic costs of meeting the RFS (Figer 2011). Conversely, Midwestern states such as Illinois, Iowa, and Minnesota, which are major crude oil or petroleum fuel importers and that produce biofuels and biomass feedstocks for biofuels, stand to benefit economically from the RIN market (Figer 2011). The level and relative impacts of the RIN market are likely to vary among states depending on future conditions such as the EPA waiving mandates or petroleum prices.

There has been little examination of how economic welfare changes are affected by interactions of the RIN market with other policies. One example stated that the elimination biofuel PTCs shifted the economic burden of meeting the RFS from taxpayers to obligated parties and consumers (Brown 2013). Taxpayers subsidize obligated parties' efforts to meet the RFS when there is a PTC. When there is no PTC, the RFS must be met by obligated parties and the consumers to whom they can pass their costs. Biofuel producers would not bear the cost of the RFS when there are no PTCs, but they would lose any benefit of the PTC.

4.4 Interactions of the RIN Market, the Blend Wall, and Ethanol Blends

The blend wall would be relaxed and obligated parties could meet RFS requirements if other ethanol blends were available in large quantities. Unfortunately, there are many technical limitations to increased use of other ethanol blends, including vehicle compatibility, pump infrastructure, pipeline/terminal/blending/distribution infrastructure, and liability issues (Searle et al. 2014; Schnepf and Yacobucci 2013; NERA 2012).

As of the end of 2013, approximately 70% of vehicles are model year 2001 or newer and are therefore approved by the EPA to use E15. Additionally, at the end of 2013 there were 17.4 million FFV vehicles registered in the United States (DOE 2014d). To date, there are over 2,500 E85 stations in the United States, with major clustering in the Midwest and large increases in available stations elsewhere in recent years (Bredehoef and Farber-DeAnda 2014). About 14 billion gallons of ethanol (i.e., E10 + tiny increases in E85 + miniscule uptake of E15) can reasonably be expected to be consumed without additional investment in overcoming the technical barriers (Babcock 2013). However, E85 demand is projected to continue to remain low (NERA 2012).

The E10 blend wall is an economic barrier that can be overcome by increasing the incentive for drivers to use E85 to fuel their vehicles (Babcock and Pouliot 2013a; Babcock 2013). Analysis in the literature indicates a potential market for larger volumes of E85 based on current flex-fuel vehicles and stations that sell E85, constrained more by the competitiveness of E85 prices than by the location of vehicles and stations (Babcock and Pouliot 2013a). In 2013, the reduction in RFS compliance costs achievable through greater E85 use could be greater than the costs of investing in E85 infrastructure (Babcock 2013). Over time, increasing the number of stations that sell E85 could decrease the ethanol price. This decrease could be enough to induce enough ethanol consumption to meet targets by making the fuel more accessible to consumers. Increased ethanol use leads to more RIN generation and lower renewable fuel RIN prices and hence lower compliance costs. Obligated parties faced with high RIN prices would have incentive to invest in the infrastructure that would facilitate increases in ethanol consumption (Pouliot and Babcock 2014). However, questions remain regarding the strength of this incentive.

E85 rarely, if ever, has been priced at a level where it saves consumers money because retailers price E85 relative to gasoline (Babcock and Pouliot 2013a; Verleger 2013). As renewable fuel RIN prices have increased, so too have the incentives to blend and sell more E85 (Pouliot and Babcock 2014). Individual retailers that have reduced the relative price of E85 to below energy equivalence with E10 have seen sales volumes increase substantially. However, sales volumes of E85 are only modestly higher than in early 2012 in Minnesota, despite a significantly more favorable price ratio (Meyer, Johansson, and Paulson 2013; Dinneen 2013; Irwin and Good 2013g; Irwin and Good2013f). There is considerable uncertainty and potential for market failure related to decisions about policy and investment in fueling infrastructure that has discouraged transition to allowing higher ethanol blends (Irwin and Good 2013g).

According to Searle et al. (2014), if a large growth in the alternative ethanol blend market is desired, ethanol fueling infrastructure subsidies are expected to be needed, and political, social, and regulatory barriers would need to be addressed. Growth in the market for alternative ethanol blends would also be aided by optimization of the octane boost for the ethanol blend (Searle et al. 2014). E10 uses the entire octane while E85 does not. The petroleum industries' investments in E85 infrastructure have reportedly been limited so far (Dinneen 2013). Policies exist to increase distribution capacity, but High RIN prices are the only current policy incentive to increase both the distribution capacity and demand for E85 (Babcock and Pouliot 2013a).

With regards to meeting RFS volumetric requirements, non-ethanol solutions to the blend wall are possible. The EPA could further encourage alternative fuels such as biogas, bioelectricity for use in transportation, renewable gasoline, cellulosic diesel (D7), and biomass-based diesel (D4) fuel production (Brown 2013; Thompson et al. 2012). However, several of these fuels displace diesel rather than gasoline. In addition, the available volume of at least biodiesel is beginning to run up against production capacity constraints, at least in the short-term (NERA 2012). Increased incentive to use biofuels that displace diesel could lead to longer-term changes in diesel vehicle use that would address the blend wall itself.

Section 5. Analysis of RIN Market Price Drivers

5.1 Overview

The legal and regulatory context of the RIN market from Section 2 outlines the structure of the market. The literature review in Section 4 documents the major historic drivers of RIN market prices. The combination of insights from these sections highlights how various markets, policies, and other factors relate to RIN market price changes over time. These retrospective insights can be used to analyze the current state of the RIN market, as well as potential future changes and their implications. The goal of Section 5 is to analyze the current state of the main drivers of the RIN market in order to gain insights on potential strategies for meeting the RFS in future years. Section 5 analyzes RIN market prices by:

- Creating a mathematical representation of the definitions and constraints of the RIN market based on the legal and statutory context of the RIN market from Section 2
- Summarizing the major RIN market drivers from Section 4
- Summarizing the current state of RIN price drivers with regards to the ethanol blend wall
- Analyzing potential pathways for meeting the RFS mandates even with the blend wall constraints.

5.2 Summary of Key Historic RIN Market Drivers

Section 4 documents a literature review of the major RIN market price drivers. In general, the key drivers of RIN market prices are:

- Biofuel market conditions as determined by biomass feedstock production and infrastructure constraints like the blend wall.
    - The RFS may be non-binding if other factors (e.g., economic or policy) are driving biofuel use, in which case the RIN market prices will be near $0.
    - A binding RFS forces obligated parties to use more biofuels than they otherwise would. In this case, the RIN market price becomes the gap between an obligated party's WTP for biofuels and the implicit price of the biofuels.
- EPA mandates of renewable fuels (D6) (i.e., EISA 2007) and how mandates translate into RVOs for obligated parties. Increased mandates increase RVOs, which increase the required RINs and then increase RIN prices.
- The price convergence, which is a natural result of the nested structure of RIN categories. Convergence would be expected when the price of the most inclusive RIN (i.e., renewable fuel) biofuel category is similar to the least inclusive RIN biofuel category. It occurs when less inclusive RIN categories (i.e., cellulosic) can satisfy requirements for the most inclusive biofuel category (i.e, renewable fuel).
- RIN market participant expectations about the above drivers influence trading on the RIN market.

From Figure 3.12, low renewable fuel (D6) RIN prices until 2013 suggest a non-binding RFS where biofuel use was not higher than obligated parties desired economically. Major renewable fuel RIN price increases in early 2013 reflected draw down of RIN stocks, a looming blend wall, and expectations that the EPA would not waive the EISA 2007 mandates. Renewable fuel RIN price decreases later in 2013 reflected gradual release of information, indicating improved RIN stocks for 2013 and potential waiving of the EPA mandates.

Biomass-based diesel (D4) and advanced biofuel (D5) RIN prices until late 2012 were high, reflecting the prices of these biofuels relative to petroleum-based diesel. As biomass-diesel production ramped up in anticipation of the value of biomass-based diesel RINs to meet renewable fuel RVOs, the biomass-based diesel prices began declining until the major increases in the renewable fuel RIN price. During parts of 2013, all RIN prices converged because of the nested structure of the RIN categories and increases in renewable fuel RIN prices. Finally, at the end of 2013, as renewable fuel RIN prices decreased, biomass-based diesel and advanced biofuel RIN prices decreased until the biomass-based diesel RIN price decoupled from advanced biofuel and renewable fuel. Biomass-based diesel RIN prices become related to the WTP forbiomass-based diesel and therefore the costs of the biomass-based diesel and diesel fuel prices.

5.3 The State of Current RIN Market Drivers

The literature review in Section 4 (also summarized in Section 5.2) indicates that the RIN market is currently mostly driven by conditions associated with the renewable fuel (D6) RIN market price.[8] The RIN prices for renewable fuels (D6) prior to 2013 were non-binding and thus the RIN prices were very low (<$0.05/RIN). Historically, ethanol's value as a substitute for MTBE was the primary driver for ethanol use. In 2013, petroleum producers, believing that EPA would maintain the RFS mandates for all categories, began to accumulate RINs believing that it was going to be difficult to meet the mandates which increased the RIN market price for renewable fuel (D6). This was the first time that renewable fuel (D6) mandates became binding and the price for a renewable fuel RIN spiked above $1.30/RIN.

Figure 5.1 shows historic data that illustrate how a combination of lower-than-expected petroleum use and the ethanol blend wall had contributed to slow growth in ethanol use as of 2013-2014. This trend may lead to the question of not why the RIN value spiked in 2013, but why it took so long. The blend wall has long been recognized, and based on recent EIA predictions on U.S. gasoline use, the United States was expected to reach the blend wall sometime in 2013 or 2014. The literature suggests that the slow response may have been due to the uncertainty of whether the EPA would maintain the future RFS2 volumetric mandates, recognizing that there would not be a market for ethanol above the 10% blending requirement (Thompson et al. 2012). The reductions in RIN values later in 2013 and 2014 were in response to rumors surrounding EPA comments that suggested reduction in the total volumetric mandates, and thus, reduction in the number of RINs needed to meet the obligations (Brown 2013; Yeh and Witcover 2014).

The result of the increase in the renewable fuel (D6) RIN price, which is the most inclusive RIN category, was the convergence of RIN prices across all biofuel categories. The increase of the other RIN category prices was the result of the increase in demand in order to satisfy the renewable fuel mandate. The cause of this trend is the expense of meeting the RFS requirements

[8] Cellulosic biofuel (D3) prices continue to be mostly driven by the price of equivalent cellulosic waiver credits offered by the EPA, and are therefore not analyzed in Sections 5.4 and 5.5.

by, for example, blending more biodiesel. The other categories' prices are driven up because of the nested structure of the RIN biofuel categories. In the near term, the transportation fuel industry is expected to be constrained by the blend wall in meeting renewable fuel (D6) RFS requirements. Therefore, increasing binding mandates will drive up the renewable fuel RIN price along with all other RIN prices, at least in the short-term. Recent trends in RIN market prices are by design. Under high demand for RINs for petroleum producers to meet their RVOs, the RIN price would increase, which would signal to the petroleum producers that new investments are necessary. Section 5.4 covers ways that RIN market prices could be mitigated in the near and long-term.

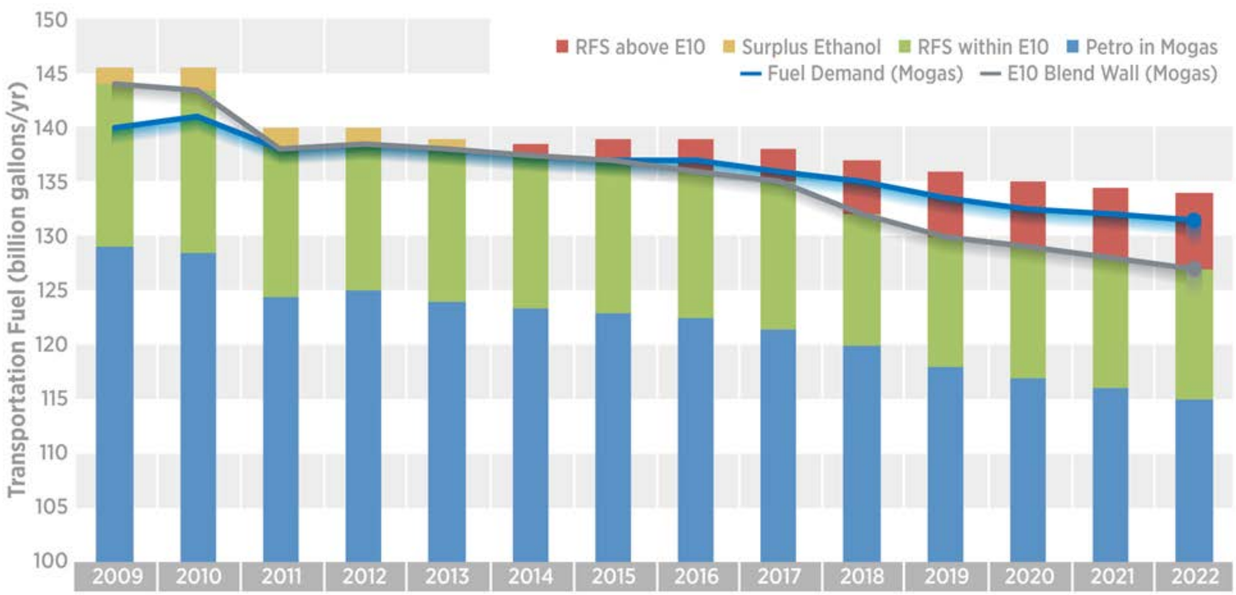


Figure 5.1. Illustration of the onset of the E10 blend wall starting in 2013-2014 (billion gallons per yr)

Chart based on AEO 2012 and EISA volume mandates for RFS2 for conventional and advanced biofuel (D5) (less biomass-based biodiesel). As gasoline use continues to decline, so will the blend wall (EIA 2014a; 40 CFR 80). Petro in Mogas = petroleum in motor gasoline.

5.4 Meeting the RFS in the Context of the Ethanol Blend Wall

Based on information presented in Section 5.3, several options for meeting the RFS despite the ethanol blend wall have been explored in the literature review of Section 4. Section 5.4 contains our summary and analysis of options for meeting the RFS despite the blend wall; some of this information is summarized in Table 5.1. These methods have already been examined in the literature, as well as their potential effects on the RIN market. However, we recognize that the future of the RFS is not possible to predict. In reality, a combination of these options, and/or possibly others that we have not considered (e.g., congressional legislation), will allow for compliance with the RFS.

Table 5.1 Some Potential Options for Meeting the RFS in the Context of the E10 Blend Wall

Options	Description	Potential Challenges
Reducing Petroleum Fuel Production	Reduction of RIN obligations by decreasing the volume of transportation fuel produced.	Fuel price increases (at least in the short-term)
Increased Production and Use of Higher Ethanol Blends	Increased production and use of higher ethanol blends such as E15 and E85 that alleviate the E10 blend wall.	1. Requires changes and adoption of new infrastructure and vehicles by consumers and industry 2. Requires changes in regulatory policies 3. Depending on implementation it may increase fuel prices
Increased Production of Non-Ethanol Biofuels	Increased production of biofuels unconstrained by the blend wall, but that can generate RINs.	Deployment limitations such as time for infrastructure build out, feedstock constraints on the size of the biorefineries, and the level of commercialization.
Increased Importation of Non-Ethanol Biofuels	Increased importation of biofuels unconstrained by the blend wall, but that can generate RINs.	Energy security associated with relying on foreign production.
Waiving the Renewable Fuel Mandate	Reduce the renewable fuel mandates so that fewer RINs are need to be in compliance with the policy.	1. Reduced incentives for biofuel production and use. 2. Reduced price support for biofuel feedstocks.

5.4.1 Reducing Petroleum Fuel Production

Section 5.4.1 elaborates on the binding and non-binding mandate concepts introduced in Section 4 and shown in Figure 4.1.

If the EPA maintains the volume mandates, obligated parties, each acting independently, could reduce their RIN obligations by decreasing the volume of transportation fuel supplied to the domestic market (NERA 2012). The reduction in domestic supply would tend to drive up the price of gasoline. However, other literature indicates that keeping the RFS mandates will not increase the price of gasoline in the long-term. The increase in gasoline prices would reduce demand, which would reduce the RIN price and the cost of ethanol; this would incentivize domestic fuel sales and E85 infrastructure investments, and thereby reduce exports, effectively establishing a stabilizing feedback loop (Pouliot and Babcock 2014). Literature indicates clearly that the price interactions of supply chain participants are still largely unknown (Irwin and Good 2013b).

Figure 5.2 shows the impact of a shift on the wholesale price of gasoline (Pouliot and Babcock 2014). The shift up in the supply curve of gasoline increases the market-clearing price of gasoline from P1 to P2 and decreases the quantity sold from Q1 to Q2. This shift in the supply curve means that obligated parties faced with the added cost from RINs will reduce petroleum fuel production in order to reduce biofuel use obligations and maximize their profits.

Relatively speaking, higher gasoline prices would make ethanol more competitive in the fuels market, but the gasoline price increment also raises ethanol prices because ethanol production utilizes petroleum (e.g., transporting ethanol via tanker). However, the magnitude of the gasoline price increase is less than the cost increase in gasoline due to obligated parties purchasing RINS, which means that some of the cost increase is borne by buyers of wholesale gasoline (i.e., blenders) and some by gasoline producers. This is a standard result in economic analyses that attempt to estimate the impact of a tax on production (Pouliot and Babcock 2014). As shown in the second frame of Figure 5.2, producers bear more of the impact when their quantities supplied are less sensitive to a price increase than the quantities demanded by consumers. The slope of the demand curve is determined by the elasticity of gasoline consumption based on price. The less elastic and steeper the demand curve, the more of the cost will be paid by the consumer.

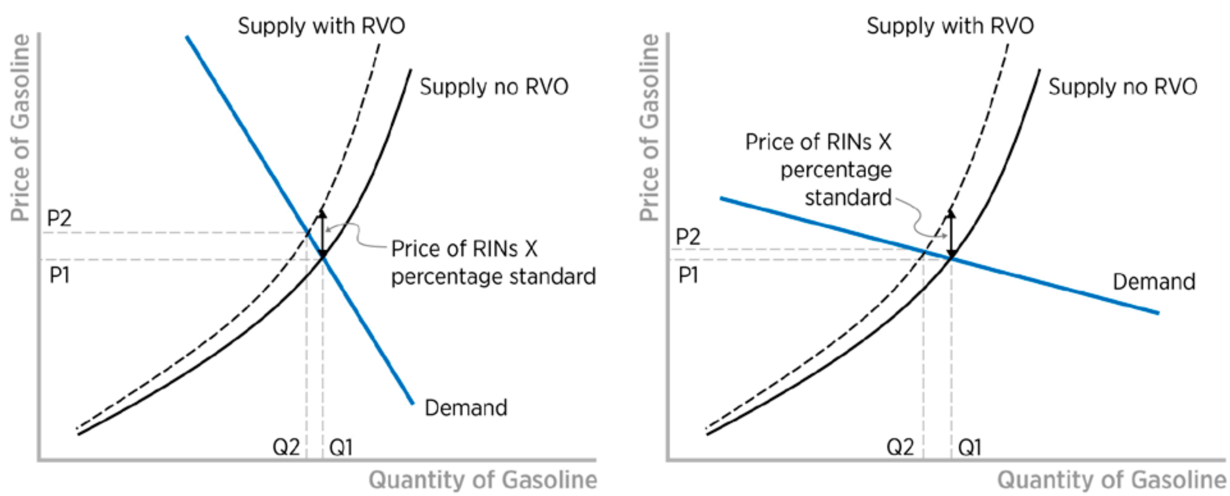


Figure 5.2. The impact of a mandate on the price of gasoline

Source: Pouliot and Babcock (2014)

5.4.2 Increased Production and Use of Higher Ethanol Blends

Another option for obligated parties is that they could use higher blend rates than E10. E15 and E85 are current options, but each has constraints that would need to be overcome before large quantities could be moved into the marketplace.

E15 is approved for light-duty cars and trucks newer than 2001; however, it is available at a limited number of stations. To sell E15, a retail station must register with the EPA and should upgrade its existing dispenser with an Underwriters Laboratories-approved retrofit kit, replacing hanging hardware, and check that its existing tank is compatible and then clean it as necessary when switching the storage fuel type in any tank.[9] Additionally, E15 and E85 are replacing E10, but the impacts are not as significant for E15 as an E85 blend since it is only adding an extra 5% while E85 would replace up to 65% gasoline per gallon (note: E85 means blends from 51% to 83% ethanol. Typical blends usually do not exceed 75%).

Most stations selling E85 added it with a waiver from their local authorities having jurisdiction (typically a fire marshal). Specially designed equipment meeting Underwriters Laboratories requirements was not available until after many stations were selling E85. Unlike E15, there is not a retrofit kit for E85—it requires a new dispenser with specialized elastomer and metal materials. Currently there are approximately 2,500 E85-capable stations out of 156,000 total stations in the United States (DOE 2014b, DOE 2014c). Furthermore, approximately 17.4 million FFVs or 6.4% of total vehicles in the United States are E85-capable as of the end of 2013 (DOE 2014d). There is a mismatch on FFV locations versus E85 availability. Many of the FFVs are on the West and East coasts, but most of the E85 stations are centered in the Midwest. Pouliot and Babcock (2014) contend that it would be less expensive for gasoline producers to invest in E85 infrastructure than to meet the mandate by purchasing higher cost RINs. Pouliot and Babcock's (2014) results center around the reduced gasoline consumption under E85 versus the price of the RFS mandate. In other words, it would be less expensive for petroleum producers to invest in E85 infrastructure—which would allow more ethanol into the market and decrease the RIN prices—than to continue with the current ethanol blend wall restrictions and pay higher RIN prices to meet the mandate.

As outlined above, E85 is not currently regulated under the EPA's fuels program. However, this fuel is subject to specification by ASTM, which requires a minimum level of volatility that varies by season and geography. Conversely, in order to ensure E85 quality and to reduce sulfur content, the EPA has issued guidance stating that any blendstock used to make E85 must be in compliance with applicable reformulated gasoline (RFG) regulations, including those setting a maximum volatility for the blendstock.

Manufacturing high-ethanol-content E85 at the minimum volatility of the ASTM specification is often not possible using the low-volatility blendstock required by the EPA guidance. Manufacturers can only comply with both requirements by reducing the ethanol content of E85 closer to the 51% minimum level, which increases the volatility of the blend while leaving the volatility of the non-ethanol blendstock unchanged. The EPA is proposing to address this problem by directly regulating E85 in its recently released Tier 3 regulations. In doing this, the EPA believes it can remove the requirement that only RFG be used for higher blend fuels.

5.4.3 Increased Production of Non-Ethanol Biofuels

Increased production and use of advanced biofuels (D5) and biomass-based (D4) diesel fuels are an alternative in meeting renewable fuel obligations. As noted in Section 4, this strategy appears to already be in use. Biodiesel capacity utilization has increased alongside increased use of atypical fuels such as biogas and non-ester renewable diesel.

[9] The vast majority of tanks in the U.S. are compatible with blends of up to E100. Information is available in the Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends.

Under the new rule, ethanol, renewable diesel, jet fuel, heating oil), and naphtha produced from energy cane cellulosic feedstock can now qualify to generate cellulosic biofuel (D3) RINs. In addition, renewable diesel (including jet fuel and heating oil), naphtha, and liquefied petroleum gas made from camelina feedstock are now eligible for advanced biofuels RINs.

The U.S. Dairy Association and others are considering biogas, not only for RFS compliance, but also for its potential to relieve waste issues. The White House released a Biogas Opportunities Roadmap highlighting the economic and environmental benefits and potential for biogas systems in the United States (USDA, EPA, DOE 2014). According to the Roadmap, biogas systems offer a wide range of potential revenue streams, growing jobs and boosting economic development for communities, businesses, and dairy farms. The systems work by recycling organic material—including cow manure and food waste—into valuable coproducts such as renewable energy, fertilizer, separated nutrients, and cow bedding.

Fuel oil presents some unique opportunities. There has been a push for several years to relieve the high cost of fuel oil in the Northeast by supplying biofuel oil. Now fuel oil qualifies under the RFS. The problem is that most biofuel is produced in the Midwest and transportation to the Northeast will be costly.

Increased deployment of non-ethanol biofuels could be limited in several key respects.. For example, some fuels such as biogas are limited by the availability of feedstocks. Deployment would also have a delay associated with infrastructure build out, and the scale of the biorefineries that can be built limits the impact of the biofuel system. Non-ethanol biofuels as newer technologies are also subject to investment risk preventing investment.

5.4.4 Increased Importation of Non-Ethanol Biofuels

The differentiation through RIN classification of the commodity by process or inputs versus physical characteristics opens the door for arbitrage where a physically identical product is cross-shipped between countries or trade is reorganized based on different compliance systems. It is generally assumed that much of the implied advanced biofuel (D5) gap of the RFS2 would have to be sourced from imported sugarcane ethanol or through additional use of bio-based diesel above its own mandate, as no other competitive fuels currently exist in the United States. The size of the undefined advanced biofuel gap is likely to influence the volume of U.S. imports of ethanol from Brazil (Meyer, Johansson, and Paulson 2013).

Before 2010, the United States was a net importer of ethanol to fulfill the demand of its domestic ethanol market, most of it coming from Brazil and the Caribbean area. After 2010 the United States became a net exporter of ethanol, mainly to Canada, the EU, and in 2011, also a considerable amount to Brazil. Since 2011, large volumes of sugar cane-based ethanol have been imported from Brazil, while considerable amounts of corn-based ethanol from the United States are exported to Brazil (Figure 5.4).

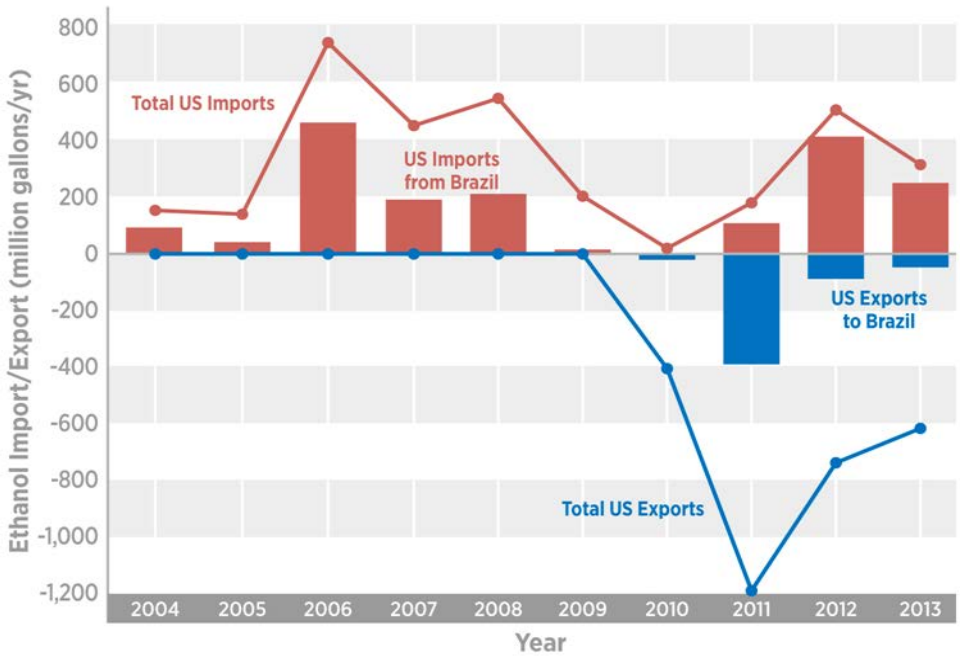


Figure 5.3. Ethanol imports and exports (million gallons per year) from the United States, and from trade with Brazil

Source: EIA (2014c)

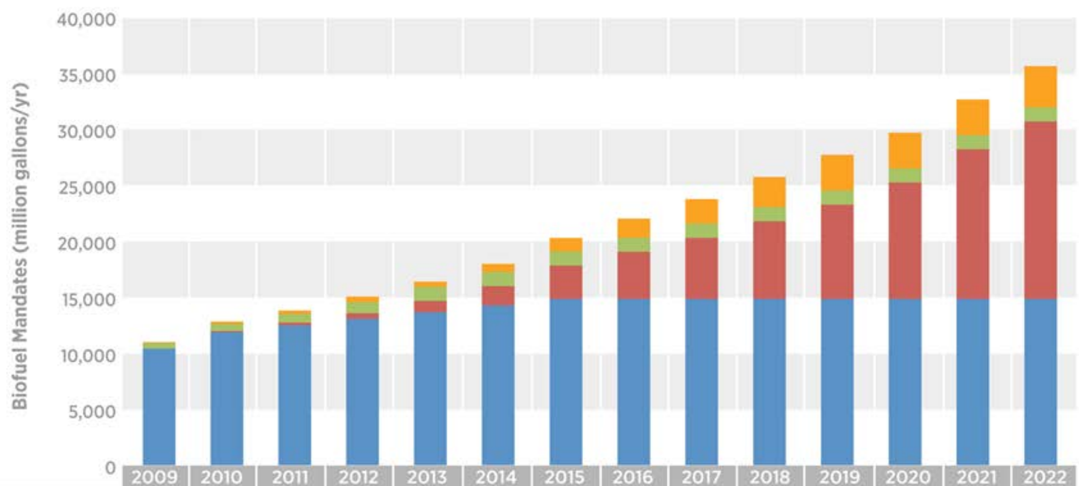
This new situation can also be seen in Figure 5.3, which displays total ethanol imports and exports from Brazil. While in the 1990s Brazil relied heavily on imports to fulfill its domestic ethanol demand, this situation changed around 2000 and Brazil became the largest exporter of ethanol. Meanwhile, exports have more or less stabilized, and there were even imports of ethanol to Brazil, most actually coming from the United States.

5.4.5 Waiving the Renewable Fuel Mandate

The EPA proposed waiving EISA 2007 advanced biofuel (D5) and renewable fuel mandates in the 2014 RFS. The EPA considered, but did not grant, waivers for 2012 due to a large number of banked RINs still being available to meet the standard (Paulson 2012b). As described in Section 2.3.4, the proposed 2014 RFS is based on inadequate "supply" due to the ethanol blend wall. The EPA explicitly considers banked RINs to be too low for 2014 and states that the stock of banked RINs should remain high to allow for flexibility in the RFS2 system (Paulson 2013b).

Currently, the biofuel industry is at the blend wall. Besides petroleum fuel pricesthere is no economic incentive for additional ethanol demand without the RFS2 mandates. So, for budding industries such as cellulosic biofuel (D3) without a guaranteed market for the product, it will be difficult for any new production capacity to start construction. The RFS2 mandates are a strong indication to the financial institutes that the United States supports cellulosic biofuel (D3). As shown in the chart below (Figure 5.4), starting in 2010, cellulosic biofuel is predicted to become a major contributor to the ethanol fuel market. So far, cellulosic biofuel production has lagged behind the estimated RFS2 mandates that were originally predicted. As the blend wall starts to impact the biofuel markets, any reduction in the mandates will send mixed signals to the financial institutes, which will lead to increased reluctance to fund any cellulosic conversion facility.

The figure below indicates that cellulosic ethanol was viewed as a technology that the United States was banking on for future liquid fuels; reducing the mandates could stunt the growth of the industry.



		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
T	Other Advanced Biofuels (A)	100	200	300	500	470	720	1,220	1,720	2,220	2,720	3,220	3,220	3,220	3,720
	Bio-based Diesel (B) (A)	500	650	800	1,00	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
	Cellulosic Biofules (S) (A)	0	100	250	500	1,000	1,750	3,000	4,250	5,500	7,000	8,500	10,500	13,500	16,000
	Implict Non-advanced Biofules (max)	10,500	12,000	12,600	13,200	13,800	14,400	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000

Figure 5.4. United States RFS2 biofuel targets (million gallons per yr)

Source: 40 CFR § 80, Table A.I.1-1

RIN prices have been most affected by the EPA's announcements and policies. By being consistent on their future volume mandates (the 2014 mandate for ethanol calls for 14.4 billion gallons of ethanol and the 2015 mandate would be 15 billion gallons), the EPA has the opportunity to strongly influence the evolution of the ethanol industry. Based on the 2014 EIA annual prediction of gasoline usage of 134 billion gallons, this would surpass the ethanol blend wall for E10, which would be around 13 billion gallons. High RIN prices would incentivize investment in E85 infrastructure as well as biogas, biojet, and other atypical fuels, which would remove the blend wall.

Literature has considered some potential tradeoffs of waiving the EISA 2007 mandate in 2014, one of which would be the limiting of bankable RINs in subsequent years because the 20% banking limit is based on the total RVO (Paulson 2013b).

Renewable fuel (D6) and advanced biofuel (D5) RIN prices will remain near biodiesel RIN prices if the EPA does not waive at least part of the mandate in the 2014 RFS (EIA 2013). If the EPA's justification for the waiver is that a non-binding mandate is needed to reduce high RIN prices, then the RFS for renewable fuel and advanced biofuel would need to remain low (Babcock and Pouliot 2013b; Irwin and Good 2013c). Waiving the original EISA 2007 mandate for 2014 based on EPA's proposal would still maintain incentives to preserve the current biofuel systems.

A secondary effect of waiving the mandate could be lower corn prices (Tyner, Taheripour, and Hurt 2012). Back-of-the-envelope calculations indicate an impact on corn prices of $0.10-0.15/bu, and other studies have examined price effects under alternative future scenarios (Meyer and Paulson 2012; Wang et al. 2013; Schnepf and Yacobucci 2013). Ethanol is a major product from corn; changes in ethanol prices could have major influence on corn prices. With more corn needed to make corn grain ethanol, demand would increase and correspondingly, the price for corn would increase. One side effect of the RFS has historically been the bolstering of the corn market by adding an additional use for corn. From a farm perspective, tax credits and the RFS can be viewed positively. Having additional competition for the use of corn helps assure higher aggregate market demand and diversified use helps to stabilize the corn prices, which have historically been variable (USDA 2014). Corn prices could increase if gasoline prices fall or if renewable fuel RIN stocks are drawn down (Meyer and Paulson 2012).

Keeping the original EISA 2007 mandate would continue incentives to produce advanced biofuel and biomass-based diesel (D4). RIN prices would remain high and also incentivize the use of higher ethanol blends in the long-term (EIA 2013c; Irwin and Good 2013c). For example, if the EPA sets total ethanol mandates to just below 16 billion gallons, then demand for E85 will be enough to maintain RIN prices at less than $1/gallon (Babcock and Pouliot 2013a). Some recent studies, such as Pouliot and Babcock (2014), have also looked at the impacts of the RIN market and the RFS on biofuel prices through economic scenario analysis. For example, Pouliot and Babcock's (2014) indicates that small increases in the 2014 ethanol mandate leads to small decline in the price of E10. Increased gasoline prices are more than offset by declines in the ethanol price and consumer shifts to higher ethanol blends

The EPA's decision to waive the EISA 2007 mandates has potential implications for other markets and specific regions of the United States. More details can be found in Section 4.3.6, which discusses economic welfare effects of the RIN market.

The EPA's proposals largely determine the RIN price. If U.S. government policy mandates biofuel use as prescribed in the RFS2, RIN prices will rise. This will provide an incentive for new technologies and pathways for additional biofuels, whether it is investment in E15 or E85 infrastructure or investment in naphtha, biojet, or fuel oil production. Conversely, if the EPA reduces the mandates, the RIN values will remain low and will not provide an incentive for limited investments in cellulosic biofuels (D3), E85, or other options.

Section 6. Prospects for RIN Market Analysis and Modeling

6.1. Overview

Section 4's literature review documented and analyzed many of the key RIN market drivers and subsequent impacts of the RIN market on the biofuel industry. Section 5 analyzed key RIN market drivers and potential ways to overcome the blend wall. Analysis in these sections highlighted areas of uncertainty and gaps in existing knowledge of the RIN market. These areas of uncertainty and gaps are potential prospects for additional modeling and analysis.

Many potential modeling approaches exist to help answer questions and gain insights about the RIN market. However, not all issues are well suited to modeling. In the following sections, we:

- Review types of models and their strengths and limitations
- Highlight general prospects for RIN market modeling and analysis
- Review some existing Department of Energy (DOE)-sponsored biofuel supply chain models
- Highlight RIN market modeling and analysis prospects for the reviewed DOE-sponsored models.

6.2. Types of Models Applicable to RIN Markets

Four general categories of models are applicable to the analysis of RIN markets: statistical models, optimization models, dynamic models, and agent-based models. Each type has a somewhat different purpose, and each possesses unique strengths and limitations.

Statistical models are tools for estimating probability distributions of potential outcomes by allowing for random variation in one or more inputs over time. Examples of these models are regression models, time-series models, autoregressive models, and other econometric models. They can accommodate regime switching from one type of market behavior to another qualitatively different type of behavior, as is observed in RIN markets. Random variation in inputs for future years are usually based on statistical characterization of fluctuations observed in historical data using standard techniques. Statistical models are typically explicit about the assumptions being made (e.g., which combinations of variables determine outcomes) and allow for assumptions to be checked using various techniques such as hypothesis testing. It can be difficult to incorporate extraneous factors not present in calibration data such as system shocks or modeler judgment.

Stochastic models (mathematical models, often statistical in nature, that incorporate random variables) can simplify a relatively complex issue to a few parameters, but their transparency is limited to straightforward statements about model coefficients. They are vulnerable to criticism that assumptions are too simple and unrealistic. Nevertheless, these models are well-suited to representing the volatility of quantities such as RIN prices and generating representative, stochastic time series of RIN prices over historical periods and future periods that extend historical trends.

Optimization models assume that the behavior and decision making for market entities seek to optimize a modeler-defined utility, which is often measured economically. A wide variety of economic models fall into this category, including macro-economic, computable general equilibrium and game-theoretic models. These have the strength that they are often built on neo-classical economics or similarly tested theories, but they may have difficulty accounting for factors that fall outside of that theoretical framework—particularly speculation, foresight, and assumptions about rationality. In the context of RIN markets, these models could well represent the basic features and influences in the markets and predict the implications of optimal decision making.

Dynamic models emphasize the gradual, non-equilibrium changes that occur in complex systems of interacting entities. Examples are system dynamics models and models comprised of ordinary differential equations which tend to capture transient behaviors, feedbacks, and system evolution with minimal calibration data, but these cannot be used for making robust predictions. For RIN markets, these models could represent the different qualitative or semi-quantitative regimes into which the RIN market might evolve.

Agent-based models simulate the emergent properties arising from the interaction of autonomous decision-making agents. Their strength is that they provide a high level of resolution and disaggregation and can represent high-order correlations between the modeled quantities; they tend to be difficult to convincingly calibrate. In the RIN markets, such models could represent all of the market players and the results of their collective actions.

Table 6.1 Summary of Types of Models Applicable to RIN Markets

Type of Model	Description	Strengths	Limitations
Statistical	Statistical models estimating probability distributions of potential outcomes by allowing for random variation in one or more inputs over time	Explicit about the assumptions and allow testing using various techniques	Difficult to incorporate extraneous factors not present in calibration data such as system shocks.
Stochastic	Simplifying models, typically statistical, that incorporate random variables	Simplifies a relatively complex issue to a few key parameters	Assumptions may be too simple and unrealistic
Optimization	Models that assume that behavior and decision-making optimize a modeler-defined utility	Built on neo-classical economics or similarly tested theories	Difficulty accounting for factors that fall outside of that theoretical framework such as irrationality, speculation, and foresight
System Dynamics	Models that emphasize the gradual, non-equilibrium changes that occur in complex systems	Captures and easily conveys feedback effects of complex systems over time	Cannot be used for making robust predictions because of focus on high-level dynamics
Agent-based	Models that simulate the emergent properties arising from the interaction of autonomous decision-making agents	Provides a high level of system resolution and disaggregation	Difficult to convincingly calibrate

6.3. Prospects for RIN Market Modeling and Analysis

In Sections 3, 4, and 5, the review and analysis of existing data and literature on the RIN market clearly indicates a key set of drivers that have shifted in importance over time. These sections also document evidence from the literature on how the RIN market has impacted biofuel and other markets historically. Some aspects of the RIN market, such as key drivers and prominent trends in RIN market prices, can be analyzed and represented using models such as those described in Section 6.1.

RIN market features that are amenable to representation in a model, based on theory and empirical experience, include:

- Identification of key drivers of the RIN market and the relative importance of key drivers in determining RIN market prices
- Impacts of existing and potential future policies on shaping how the RIN market functions and subsequently affects the biofuel market
- Interactions of the RIN market with other policies such as PTCs
- Major trends in RIN market prices given the various key driving forces, including changes in policy such as waiving EISA 2007 mandates

- Characterization of bounds on variance in current and potential future RIN market price. A variance bounding analysis could be undertaken based on an understanding of key drivers and major trends in the RIN market.

Examining these features under unprecedented future conditions would be an additional analytical step.

Several issues in the RIN market are not well-suited to being analyzed using models. Models are unlikely to be able to address research questions related to forecasting or prediction of the RIN market. Literature indicates that the current volatility of RIN market prices are linked to the uncertainty common in a new market and the major role market participants' expectations have in influencing prices. These quickly shifting behavioral trends are difficult to study via a model. For example, models are not well-suited to anticipating the effects of information shocks to the system, such as when the EPA announces the proposed and final RFS, or when Congress changes biofuel tax policies. Information shocks can be studied retroactively and generalized system shocks can be modeled prospectively, but anticipating or forecasting specific system shocks is not feasible.

All models face the limitation that scenarios, algorithms, and data can only approximate the reality that they represent. These limitations are especially true for the RIN market, which is composed of fluid regulation and complex processes, with few and imperfect historical precedents. In summary, models are unlikely to predict the future, but may provide insights about possible futures. Modeling results should be interpreted accordingly.

6.4. Discussion of Several Existing Bioenergy Models

DOE sponsors several biofuel system models that could be modified or further developed to include the RIN market for analysis. These models include Idaho National Laboratory's (INL) Biomass Logistics Model (BLM), the National Renewable Energy Laboratory's (NREL) Biomass Scenario Model (BSM), and Oak Ridge National Laboratory's (ORNL) Biomass transportation (BioTrans) model.

The system dynamics approach identifies complex feedbacks and bottlenecks among the different parts of the biomass and biofuels industries as they develop, and provides a complementary approach to other methods of modeling biofuels, such as economic equilibrium modeling (Sterman 2000). INL and NREL created system dynamics models of the biomass logistics and biomass-to-biofuel supply chain, respectively.

INL's BLM estimates delivered feedstock cost and energy consumed for biomass feedstock supply systems. The BLM is a state-of-the-art dynamic model that uses system dynamics to simulate (not optimize) dynamic interactions across the biomass supply chain. It evaluates the economic performance, energy consumption, and greenhouse gas performance of the biomass supply chain system. The BLM incorporates information from a collection of databases that provide 1) engineering performance data for equipment systems, 2) spatially explicit labor cost data sets, and 3) local tax and regulation data. The BLM simulates the flow of biomass through the biomass supply chain, accounting for all of the equipment that comes into contact with biomass from the point of harvest to the gate of the conversion facility, and the change in biomass characteristics (e.g., moisture content). The BLM is designed to work with thermochemical- and biochemical-based biofuel conversion platforms and accommodates a range of cellulosic biomass types (e.g., short-rotation woody and herbaceous energy crops).

INL has also developed a dynamic computer simulation model that analyzes future behavior of bioenergy feedstock markets given policy and technical options (Jeffers, Jacobson, and Searcy 2013). The model simulates the long-term dynamics of these markets by treating advanced biomass feedstocks as a commodity and projecting the total demand of each industry, as well as the market price over time. The model is used for an analysis of the U.S. bioenergy feedstock market and projects supply, demand, and market price given three independent buyers: domestic biopower, domestic biofuels, and foreign exports.

NREL's BSM uses a system dynamics simulation (not optimization) to model dynamic interactions across the biofuel supply chain. The BSM models the U.S. domestic biofuels supply chain with explicit focus on policy issues and biofuel feasibility, and the resulting potential side effects. It integrates resources availability, physical/technological/economic constraints, behavior, and policy. The BSM tracks the deployment of biofuels given technological development and the reaction of the investment community to those technologies in the context of land availability, the competing oil market, consumer demand for biofuels, and government policies over time. The BSM is currently used to develop insights into the biofuels industry growth and market penetration, particularly with respect to policies and incentives applicable to each supply chain element (e.g., subsidies, carbon caps/taxes, and R&D investment).

ORNL's BioTrans economic model optimizes the social surplus from the light-duty vehicle fuel transportation market. It operates through a long-run and short-run dynamic optimization model by using a general algebraic modeling system. The long-run BioTrans leverages outputs from other models (e.g., INL's BLM) and integrates those outputs into a supply chain model, with summary representations from these models for annual runs over 20 years. It balances markets and determines fixed capital such as biorefineries and it feeds into BioTrans short-run stochastic simulations over a year to examine shocks from the oil system and weather to assess infrastructure reliability. Overall, the BioTrans model focuses on biomass resource assessment, biomass logistics, and alternative fuel representation and provides the inputs to compute energy security and sustainability indicators.

6.5 Recommended Research Pathways

Retrospective analyses have not focused much on the behavior of participants in the RIN market such as RIN banking behavior. Retrospective research has focused on key RIN market drivers, issues, and the potential impacts of the RIN market on the biofuel industry.

Recent analysis of the implications of the EPA waiving renewable fuel (D6) and advanced biofuel (D5) requirements highlights the role that shifting policies could play in driving the RIN market and the corollary impacts on the biofuel industry. Most of the selected literature offers reports on retrospective rather than prospective analytic research and modeling. Although these efforts offer initial prospective analysis, additional prospective modeling and analysis would be needed to develop a better understanding of RIN market participant behaviors (e.g., RIN banking), examine alternative policy scenarios and regime changes, and evaluate the impacts of RIN market on biofuel markets. A few prospective modeling and analytic studies exist, but they focus on near-term (i.e., next year) changes in the RIN market (e.g., Irwin [2014], Pouliot and Babcock [2014]).

Potential general research topics include:

- RIN market participant behavior analysis
- Assessment of the RIN market's impacts on biofuel systems
- Scenario analysis of potential changes in policies, RIN market regime shifts, and evolving contextual conditions such as petroleum fuel prices.

Many market participant behaviors are not well analyzed or understood. RIN behaviors are mostly known at aggregate levels such as through daily RIN market prices, monthly national RIN generation, and annual stocks of RINs. For example, analyzing the presence and magnitude of market speculation is one possible research route, but trade volume data is not currently available for such modeling or analysis. Other potential research areas include:

- Understanding to what extent the market is or is not responding to policy announcements
- Estimating the ranges of biofuel market effects that RIN markets could have, with and without constraints from litigation
- Analyzing the evidence for end-of-year jumps in RIN prices or cyclical trends tied to season variations
- Evaluating the potential for "zombie" RINs through long-term storage of biofuels
- Assessing the role of changes in policy in effecting price stability, or more generally, how price stability may have changed over time
- Examining trends in RIN banking behavior
- Examining other pathways for moving past the "blend wall" such as biogas, naphtha, and other fuels
- Exploring atypical strategies used to meet RFS requirements, such as obligated parties using biofuels in their supply systems
- Developing scenarios that feature various levels of international trading of biofuels.

Historic data and literature indicate that the RIN market has influenced the market development of biofuels systems. For example, biomass-based diesel (D4) and advanced biofuel RIN prices have potentially played a role in increasing the production and import of biofuels in these categories (Babcock 2012; McPhail, Westcott, and Lutman 2011). A notable gap in the literature is a complete analysis of the potential for the RIN market price to play a role in developing alternative fuel systems such as renewable hydrocarbon fuels in various future scenarios. Another example noted in Section 4 is that RIN market prices in 2013 were just beginning to push E85 to price parity with E10 in some regions. Modeling and analysis of E85 market dynamics under a RIN market in various future scenarios could help improve our understanding of the barriers to increased E85 use.

A variety of current or potential future public policies already do or could eventually contribute to major changes in the RIN market prices. The RIN market is influenced by changes in policies such as RFS mandate waivers, tax credits, and others. Future policy changes could affect the RIN market and consequently biofuel market development. Quantitative capabilities to model different policy regimes would help develop insights around the potential impacts of changes in policy on the RIN market and biofuel systems. Discussions of new bioenergy policies could then be better informed through analysis of alternative policy scenarios.

We recommend that researchers focus on modeling and analysis along the three main research pathways proposed above. Our recommended research pathways are not exhaustive, but concentrate on addressing key research gaps identified from our literature review. Such analysis could build on previously developed frameworks to simulate RIN market effects on the growth of biofuel industries based on economic drivers including biomass competition, federal and state policies, and foreign competition. The goal of the analysis would be to (1) assess the impacts of regulatory (both current and future state and federal), market, and technology drivers on the growth and evolution of individual biofuels pathways and (2) identify potential problems, such as unintended price instability, unintended byproduct dominance, and unintended policy effects, which can be projected by dynamic modeling of the bioenergy economic system as a whole. Furthermore, by analyzing the impact of policies on each economic driver, policies may be tested and eventually crafted to be more effective in advancing national policies.

Section 7. Conclusions

7.1 Overview

The future of the RFS2 program (and the RIN market) will be determined largely by the extent of the EPA's authority under the RFS2 program, and court challenges to the EPA's authority have gone both ways. The future may also be impacted by legislation amending the program. Regardless of the outcomes of legal challenges and legislation, these decisions will have a large impact on the future of the RFS2 program with implications for the biofuel industry.

Existing literature has examined many of the historic drivers of the RIN market and documented the impacts of the RIN market. The RIN market has played a limited role in renewable fuel use. It may have contributed to increased corn ethanol exports ad increase sugarcane imports. The RIN market has likely played a role in recent increases in production and importation of biomass-based diesel (D4) and advanced biofuel (D5). The RIN market has made economic transfers from obligated parties to biofuel producers and has served as an indirect crop price support for biofuel feedstock producers. To date, literature suggests that RINs have had a negligible impact on gasoline prices,[10] but diesel prices–where impacts would be more likely–have not been well studied.

Existing modeling and analysis have focused on retrospectively determining the drivers of RIN markets and the impacts of the RIN market. Prospective analysis has generally been short-term and focused on only minor changes to policies. There are many modeling and analysis opportunities related to more prospective research into longer-term issues related to changes in policies, major RIN market regime changes, and scenario analysis of alternative contextual conditions, such as petroleum fuel prices. We recommend researchers focus on modeling and analysis in the following key areas:

- Examining the RIN market price's role in developing alternative fuel systems, such renewable gasoline and diesel fuels that fit within the existing petroleum supply chain in various future scenarios
- Analyzing alternative policy scenarios. Quantitative capabilities to analyze different policy regimes would help clarify the potential impacts of the RIN market on biofuel systems since the RIN market is affected by mandate waivers, tax credits, and other policy changes
- Examining E85 market dynamics under a RIN market in various future scenarios
- Analyzing RIN market participant behaviors through trade volumes, banking, and other strategies used by obligated parties and other RIN market participants.

The above recommended research pathways are not exhaustive, but focus on addressing key research gaps identified from the literature reviewthat would be important to understanding how the RIN market can or could influence that development of the biofuels market in the future.

[10] Increasing the volume of biofuels used in the transportation system will increase prices if the biofuels cost more on an energy-equivalent basis than the petroleum fuels they displace. This is an effect of the RFS itself rather than the RIN market.

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Appendix A. Legal and Regulatory Definitions

A.1 Definitions

Advanced biofuel (D5) is defined as "renewable fuel, other than ethanol derived from corn starch, that has life-cycle greenhouse gas emissions...that are at least 50 percent less than baseline lifecycle greenhouse gas emissions" (42 USCS § 7545 (o)(1)(B)(i)). This includes the following types of fuel:

- "Ethanol derived from cellulose, hemicellulose, or lignin
- Ethanol derived from sugar or starch (other than corn starch)
- Ethanol derived from waste material including crop residue, other vegetative waste material, animal waste, and food and yard waste
- Biomass-based diesel (D4)
- Biogas (including landfill gas and sewage waste treatment gas) produced through the conversion of organic matter from renewable biomass
- Butanol or other alcohols produced through the conversion of organic matter from renewable biomass
- Other fuel derived from cellulosic biomass" (42 USCS § 7545 (o)(1)(B)(ii)).

EPA approved advanced biofuel (D5) fuel pathways are available on EPA's website (2015a). Pending petitions for approval are also available on EPA's website (2015b).

Baseline lifecycle greenhouse gas emissions is defined as "the average lifecycle greenhouse gas emissions...for gasoline or diesel (whichever is being replaced by renewable fuel) sold or distributed as transportation fuel in 2005" (42 USCS § 7545 (o)(1)(C)).[11]

Biomass-based diesel is defined as "renewable fuel that is biodiesel as defined in section 312(f) of the Energy Policy Act of 1992 (42 USCS 13220(f)) [12] and that has lifecycle greenhouse gas emissions...that are at least 50 percent less than the baseline lifecycle greenhouse gas emissions" (42 USCS § 7545 (o)(1)(D)). EPA regulations have extended the biomass-based diesel (D4) definition by requiring that fuel:

- "Is a transportation fuel, transportation fuel additive, heating oil, or jet fuel
- Meets the definition of either biodiesel[13] or non-ester renewable diesel[14]

[11] Gasoline contained a baseline level of 98 g CO_2eq/MJ, while diesel contained a baseline level of 97 g CO_2eq/MJ (EPA 2010c).

[12] The Energy Policy Act of 1992 defines biodiesel as "a diesel fuel substitute from non-petroleum renewable resources that meets the registration requirements for fuels and fuel additives established by the EPA under Section 211 of the Clean Air Act." The term includes biodiesel derived from animal waste, municipal solid waste and sludges, and oils derived from wastewater and the treatment of wastewater. 42 USCS 13220(f).

[13] Under 40 CFR § 80.1401, biodiesel is defined as a mono-alkyl ester that meets American Society for Testing and Materials D 6751-09, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.

- Is registered as a motor vehicle fuel or fuel additive under 49 CFR part 79 if the fuel or fuel additive is intended for use in a motor vehicle" (40 CFR § 80.1401).

Cellulosic biofuel (D3) is defined as "renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions...that are at least 60 percent less than the baseline lifecycle greenhouse gas emissions" (42 USCS § 7545 (o)(1)(E)).

Cellulosic diesel (D7) is defined as "any renewable fuel which meets both the definition of cellulosic biofuel and biomass-based diesel" (40 CFR § 80.1401).

Conventional biofuel is defined as "renewable fuel that is ethanol derived from corn starch" (42 USCS § 7545 (o)(1)(F)). Require 20% GHG emission reduction compared with a baseline plant.

The *EPA Moderated Transaction System* (EMTS) is a database through which certain EPA-regulated parties must submit information related to RINs to the EPA. Regulated parties that must create an account through the EMTS include:

- Domestic or foreign producers or importers of renewable fuel each time they assign RINs to a batch of renewable fuel pursuant to 40 CFR §80.1426(e)
- Any party that sells, separates, or retires RINs (each time sold, separated, or retired)
- Any party that purchases RINs (each time purchased) (40 CFR § 80.1452).

An *Obligated party* is defined as "any refiner that produces gasoline or diesel fuel within the 48 contiguous states or Hawaii, or any importer who imports gasoline or diesel fuel into the 48 contiguous states or Hawaii during a compliance period. A party that simply blends renewable fuel into gasoline or diesel fuel, as defined in §80.1407(c) or (e), is not an obligated party" (40 CFR § 80.1406(a)(1)).[15]

Renewable biomass is defined as "each of the following:

- Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of this sentence that is either actively managed or fallow, and non-forested
- Planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment of this sentence, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the United States or subject to a restriction against alienation imposed by the United States
- Animal waste material and animal byproducts

[14] Under 40 CFR § 80.1401, non-ester renewable diesel is defined as a fuel that can be used in an engine designed to operate on conventional fuel, or be heating oil or jet fuel and is not a mono-alkyl ester.

[15] Note that, under 40 CFR § 80.1406(a)(2), if the Administrator approves a petition of Alaska or a United States territory to opt-in to the renewable fuel program under the provisions in 40 CFR §80.1443, then the obligated party also includes any refiner that produces gasoline or diesel fuel within that state or territory, or any importer that imports gasoline or diesel fuel into that state or territory which has opted in.

- Slash and pre-commercial thinnings that are from non-federal forestlands, including forestlands belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States, but not forests or forestlands that are ecological communities with a global or State ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest
- Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire
- Algae
- Separated yard waste or food waste, including recycled cooking and trap grease" (42 USCS § 7545 (o)(1)(I)).

Renewable fuel is defined as "fuel that is produced from renewable biomass and that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel." EPA regulations have extended the renewable fuel definition to require that the fuel "has lifecycle greenhouse gas emissions that are at least 20 percent less than baseline lifecycle greenhouse gas emissions," unless exempted pursuant to 40 CFR § 80.1403 (40 CFR § 80.1401).

Renewable fuel exporter is any party that owns any amount of renewable fuel that is exported from the contiguous 48 states, Hawaii, and any territory that opts. Renewable fuel exporters must acquire sufficient RINs to comply with the RVO requirements listed in 40 CFR § 80.1430(b) (40 CFR § 80.1430).

Renewable Identification Number (RIN) is defined as "a unique number generated to represent a volume of renewable fuel" (40 CFR § 80.1401).

Renewable volume obligation (RVO) is a percentage of renewable fuel for which an obligated party is responsible based on petroleum production and the renewable fuel standard for the calendar year as determined by the EPA pursuant to 40 CFR § 80.1405 (40 CFR § 80.1407). Each category of renewable fuel has its own calculation under 40 CFR § 80.1407. An obligated party complies with the RVO through retiring a sufficient amount of RINs equal to the RVO by the compliance deadline.[16]

Small producer/importer threshold refers to renewable fuel producers or importers that produce less than 10,000 gallons a year of renewable fuel. Small producers and importers are not subject to requirements related to the generation of RINs, registration, reporting, EMTS, recordkeeping, attest engagement, and production outlook report (40 CFR § 80.1455).

A *small refinery* is defined as a "refinery for which the average aggregate daily crude oil throughput for the calendar year...does not exceed 75,000 barrels" (42 USCS § 7545 (o)(1)(K)).

Transportation fuel is defined as "fuel for use in motor vehicles, motor vehicle engines, non-road vehicles, or non-road engines (except for oceangoing vessels)" (42 USCS § 7545 (o)(1)(L)).

[16] An obligated party carrying over an allowable renewable fuel deficit would equate to less RINs being retired than the RVO required for the present year, with the deficit being retired the following year.

Appendix B. Mathematical Model of RIN Market Constraints

Appendix A presents a mathematical representation of the definitions and constraints in the RFS2 as they pertain to RIN markets. This model does not consider qualitative issues that may influence the EPA Administrator when interpreting EIA projections or qualitative language in EISA. The model also does not represent (i) the 60-day biomass-based diesel (D4) waivers or (ii) the required post-2016 modification of future volumetric mandates that are triggered by prior 20% consecutive-year or 50% single-year volumetric requirement reductions. These RIN market constraints are largely driven by conditions external to the RIN market (e.g., biofuel market) and are subject to EPA interpretation.

B.1 Fuel Categories

We start by defining notation for the fuel types discussed in RFS2:

$$\mathbb{F} = \{\text{CB}, \text{CD}, \text{BD}, \text{AB}, \text{RF}\},$$

where

$$\begin{aligned} \text{CB} &= \text{category D3 cellulosic biofuel} \\ \text{CD} &= \text{category D7 cellulosic diesel} \\ \text{BD} &= \text{category D4 biomass-based diesel} \\ \text{AB} &= \text{category D5 advanced biofuel} \\ \text{RF} &= \text{category D6 renewable fuel} \end{aligned}.$$

The nesting structure of the five fuel categories can be represented by a matrix:

$$\begin{aligned} q_{c,f} &= \text{whether fuel of type } f \in \mathbb{F} \text{ qualifies for category } c \in \mathbb{F} \\ &= \begin{array}{cc} & \begin{array}{ccccc} \text{CD} & \text{CB} & \text{BD} & \text{AB} & \text{RF} \end{array} \\ \begin{array}{c} \text{CB} \\ \text{BD} \\ \text{AB} \\ \text{RF} \end{array} & \begin{bmatrix} \text{iff not BD} & \text{true} & \text{false} & \text{false} & \text{false} \\ \text{iff not CB} & \text{false} & \text{true} & \text{false} & \text{false} \\ \text{true} & \text{true} & \text{true} & \text{true} & \text{false} \\ \text{true} & \text{true} & \text{true} & \text{true} & \text{true} \end{bmatrix} \end{array} \end{aligned},$$

where it is important to note that a given volume of cellulosic diesel (D7) may be considered as either a cellulosic biofuel (D3) or a biomass-based diesel (D4), but not both.

B.2 Mandates

The EISA legislation mandates fuel volumes for years up to 2022:

$$\begin{aligned} K_f^*(t) = {} & \text{annual EISA mandate volume for fuel category } f \in \mathbb{F} \text{ in year } t \\ & \text{in units of ethanol-equivalent gallons} \end{aligned}$$

where

t	$K^*_{\mathrm{CB}}(t)$	$K^*_{\mathrm{BD}}(t)$	$K^*_{\mathrm{AB}}(t)$	$K^*_{\mathrm{RF}}(t)$
2010	170,000,000	975,000,000	950,000,000	12,950,000,000
2011	425,000,000	1,200,000,000	1,350,000,000	13,950,000,000
2012	850,000,000	1,500,000,000	2,000,000,000	15,200,000,000
2013	1,700,000,000	1,500,000,000	2,750,000,000	16,550,000,000
2014	2,975,000,000	1,500,000,000	3,750,000,000	18,150,000,000
2015	5,100,000,000	1,500,000,000	5,500,000,000	20,500,000,000
2016	7,225,000,000	1,500,000,000	7,250,000,000	22,250,000,000
2017	9,350,000,000	1,500,000,000	9,000,000,000	24,000,000,000
2018	11,900,000,000	1,500,000,000	11,000,000,000	26,000,000,000
2019	14,450,000,000	1,500,000,000	13,000,000,000	28,000,000,000
2020	17,850,000,000	1,500,000,000	15,000,000,000	30,000,000,000
2021	22,950,000,000	1,500,000,000	18,000,000,000	33,000,000,000
2022	27,200,000,000	1,500,000,000	21,000,000,000	36,000,000,000.

The annual EPA rulemaking on volume mandates can be similarly represented:

$$K_f(t) = \text{annual EPA mandate volume for fuel category } f \in \mathbb{F} \text{ in year } t$$
$$\text{in units of ethanol-equivalent gallons}$$

where the rulemaking to date has specified the following:

t	$K_{\mathrm{CB}}(t)$	$K_{\mathrm{BD}}(t)$	$K_{\mathrm{AB}}(t)$	$K_{\mathrm{RF}}(t)$
2010	6,000,000	975,000,000	950,000,000	1,2950,000,000
2011	6,000,000	1,200,000,000	1,350,000,000	1,3950,000,000
2012	10,450,000	1,500,000,000	2,000,000,000	1,5200,000,000
2013	6,000,000	1,920,000,000	2,750,000,000	1,6550,000,000
2014	17,000,000	1,920,000,000	2,200,000,000	1,5210,000,000.

The EISA legislation constrains the EPA's rulemaking for advanced biofuel (D5) and biomass-based diesel (D4) according to the following inequalities:

$$\frac{K_{\mathrm{AB}}(t)}{K_{\mathrm{RF}}(t)} \geq \frac{K_{\mathrm{AB}}(2022)}{K_{\mathrm{RF}}(2022)} \text{ for } t \geq 2022$$

$$K_{\mathrm{BD}}(t) \geq K_{\mathrm{BD}}(2012) \text{ for } t \geq 2012 .$$

The percentage volumes are based on projections of the petroleum industry,

$$U(t) = \text{projected gasoline and diesel fuel use (excluding diesel used in ocean-going}$$
$$\text{vessels) in year } t \text{ in states/territories that have opted into RFS2, in gallons}$$

and

$$E(t) = \text{projected gasoline and diesel production from small refiners and refineries}$$
$$\text{that are exempt from RFS2 in year } t$$

so that

$$\kappa_f(t) = \text{annual EPA mandate fraction for fuel category } f \in \mathbb{F} \text{ in year } t$$
$$= \frac{K_f(t)}{U(t) - E(t)},$$

which results in these historical values:

t	$\kappa_{\mathrm{CB}}(t)$	$\kappa_{\mathrm{BD}}(t)$	$\kappa_{\mathrm{AB}}(t)$	$\kappa_{\mathrm{RF}}(t)$
2010	0.0000382	0.0062	0.00606	0.0825
2011	0.0000344	0.0069	0.0078	0.0801
2012	0.000063	0.0091	0.0121	0.0923
2013	0.0000353	0.0113	0.0162	0.0974
2014	0.0001	0.0116	0.0133	0.092.

B.3 Parties Related to RINs

The various parties (obligated or not) potentially involved with RINs are

$$\mathbb{P} = \{\mathrm{PR}, \mathrm{PI}, \mathrm{RFP}, \mathrm{RFI}, \mathrm{RFE}, \mathrm{Brok}\},$$

where

$$\begin{aligned}
\mathrm{PR} &= \text{established petroleum refinery} \\
\mathrm{PR}' &= \text{new petroleum refinery} \\
\mathrm{PI} &= \text{petroleum importer} \\
\mathrm{RFP} &= \text{renewable fuel producer} \\
\mathrm{RFI} &= \text{renewable fuel importer} \\
\mathrm{RFE} &= \text{renewable fuel exporter} \\
\mathrm{Brok} &= \text{broker or other party registered with the EPA},
\end{aligned}$$

and these can be characterized by their refining capacity, biofuel production, or import/export activities:

$$\begin{aligned}
C_i^{\mathrm{cap}}(t) &= \text{crude oil established capacity for party } i \text{ in year } t \\
C_i^{\mathrm{new}}(t) &= \text{crude oil new capacity for party } i \text{ in year } t \\
C_i^{\mathrm{imp}}(t) &= \text{petroleum fuel importation for party } i \text{ in year } t \\
P_{i,f}^{\mathrm{pro}}(t) &= \text{renewable fuel production of category } f \in \mathbb{F} \text{ for party } i \text{ in year } t \\
P_{i,f}^{\mathrm{imp}}(t) &= \text{renewable fuel importation of category } f \in \mathbb{F} \text{ for party } i \text{ in year } t \\
P_{i,f}^{\mathrm{exp}}(t) &= \text{renewable fuel export of category } f \in \mathbb{F} \text{ for party } i \text{ in year } t.
\end{aligned}$$

EISA specifies thresholds related to whether the parties are obligated or can generate RINs:

$$
\begin{aligned}
\Theta_p &= \text{threshhold for being an obligated party or RIN generator of type } p \in \mathbb{P} \\
&\quad \text{in gallons/year} \\
\Theta_{\mathrm{PR}} &= 155,000 \\
\Theta_{\mathrm{PR'}} &= 75,000 \\
\Theta_{\mathrm{PI}} &= 10,000 \\
\Theta_{\mathrm{RFP}} &= 125,000 \\
\Theta_{\mathrm{RFI}} &= 125,000 \\
\Theta_{\mathrm{RFE}} &= 0 \\
\Theta_{\mathrm{Brok}} &= \mathrm{N/A}
\end{aligned}
.
$$

B.4 Generation and Retirement of RINs

The generation of RINs is proportional to production at qualifying biorefineries or importers:

$$
\begin{aligned}
G_{i,f}(t) &= \text{RINs of fuel } f \in \mathbb{F} \text{ created by party } i \text{ in year } t \\
&= \left[P_{i,f}^{\mathrm{pro}}(t) + P_{i,f}^{\mathrm{imp}}(t)\right] \cdot H\left[P_{i,f}^{\mathrm{pro}}(t) + P_{i,f}^{\mathrm{imp}}(t) - \Theta_{\mathrm{RFP}}\right],
\end{aligned}
$$

where

$$
H(x) = \begin{cases} 0 \text{ for } x < 0 \\ 1 \text{ for } x \geq 0 \end{cases}
$$

is the Heaviside function. RINs also can be retired each year:

$$
R_{i,f}(t) = \text{RIN retirements for fuel } f \in \mathbb{F} \text{ in year } t.
$$

The other source of compliance with RIN obligations is the purchase, from the EPA, of waiver credits for the cellulosic biofuels (D3) category,

$$
W_{i,f}(t) = \text{waiver credits for fuel } f \in \{\mathrm{CB}\} \text{ purchased by party } i \text{ in year } t,
$$

at a price specified in the EISA legislation:

$$
\begin{aligned}
p_f(t) &= \text{price of waiver credits in year } t \text{ in \$/gallon} \\
&= \max\{0.25, 3.00 - g(t)\}
\end{aligned}
,
$$

where

$$
g(t) = \text{average wholesale gasoline price in year } t \text{ in \$/gallon}.
$$

B.5 Obligations and Deficits

The obligated volume is based on refining capacity, biofuels exports, and previous year deficits:

$$
\begin{aligned}
O_{i,f}(t) &= \text{obligated volume for fuel } f \in \mathbb{F} \text{ for party } i \text{ in year } t \\
&= \kappa_f \cdot (t) \left\{ C_i^{\text{cap}}(t) \cdot H\left[C_i^{\text{cap}}(t) - \Theta_{\text{PR}}\right] \right. \\
&\quad \left. + C_i^{\text{new}}(t) \cdot H\left[C_i^{\text{new}}(t) - \Theta_{\text{PR}'}\right] + C_i^{\text{imp}}(t) \cdot H\left[C_i^{\text{imp}}(t) - \Theta_{\text{PI}}\right] \right\} \\
&\quad + D_{i,f}(t-1) + P_{i,f}^{\text{exp}}(t)
\end{aligned},
$$

where

$$
\begin{aligned}
D_{i,f}(t) &= \text{deficit in obligation for fuel } f \in \mathbb{F} \text{ for party } i \text{ in year } t \\
&= \max\left[0, O_{i,f}(t) - R_{i,f}(t) + D_{i,f}(t-1)\right] \\
&\geq 0
\end{aligned}.
$$

Compliance with RIN obligations is specified by the following inequality, where V* is defined in the next section:

$$
O_{i,f}(t) - V_{i,f}^*(t) \leq \sum_{f' \in \mathbb{F}} q_{f,f'} \cdot \left[R_{i,f'} + W_{i,f'}(t)\right] \leq O_{i,f}(t) .
$$

B.6 Carry Over

So long as compliance is maintained, RIN obligations may be carried over for one subsequent year:

$$
V_{i,f}(t) = \text{carry over of RIN obligations for party } i \text{ in year}
$$

subject to

$$
0 \leq V_{i,f}(t) \leq V_{i,f}^*(t)
$$

where

$$
\begin{aligned}
V_{i,f}^*(t) &= \text{allowable carry over of RIN obligations for party } i \text{ in year } t \\
&= \rho \cdot O_{i,f}(t-1) \cdot H\left[-\sum_{f' \in \mathbb{F}} D_{i,f'}(t-1)\right]
\end{aligned}
$$

and

$$
\begin{aligned}
\rho &= \text{carry-over fraction} \\
&= 0.57
\end{aligned}.
$$

B.7 Markets

Sales and purchases of RINs can be represented by a transaction tensor:

$$
\begin{aligned}
T_{i',i,f}(t) &= \text{sales of RINs of fuel } f \in \mathbb{F} \text{ from party } i' \text{ to party } i \text{ in year } t \\
&\geq 0
\end{aligned}
$$

where

$$S_{i,f}(t) = \text{RINs of fuel } f \in \mathbb{F} \text{ sold by party } i \text{ in year } t$$
$$= \sum_{i'} T_{i,i',f}(t)$$

and

$$Q_{i,f}(t) = \text{RINs of fuel } f \in \mathbb{F} \text{ purchased by party } i \text{ in year } t$$
$$= \sum_{i'} T_{i',i,f}(t) \quad .$$

B.8 Banking

Obligated parties can also bank RINs for use in the year subsequent to their generation:

$$B_{i,f}(t) = \text{number of RINs of fuel } f \in \mathbb{F} \text{ banked by party } i \text{ in year } t$$
$$= G_{i,f}(t) - S_{i,f}(t) + Q_{i,f}(t) - R_{i,f}(t)$$

subject to

$$0 \leq B_{i,f}(t) \leq B^*_{i,f}(t),$$

where

$$B^*_{i,f}(t) = \text{allowable banking of RINs for party } i \text{ in year } t$$
$$= \sigma \cdot O_{i,f}(t)$$

and

$$\sigma = \text{banking fraction}$$
$$= 0.20 \quad .$$