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Stillwater Associates LLC conducted the analysis and prepared this report using reasonable care and skill in applying methods of analysis consistent with normal industry practice. All results are based on information available at the time of presentation. Changes in factors upon which the report is based could affect the results. Forecasts are inherently uncertain because of events that cannot be foreseen, including the actions of governments, individuals, third parties, and competitors. No implied warranty of merchantability shall apply.

ABOUT BPC
Founded in 2007 by former Senate Majority Leaders Howard Baker, Tom Daschle, Bob Dole and George Mitchell, the Bipartisan Policy Center is a non-profit organization that drives principled solutions through rigorous analysis, reasoned negotiation and respectful dialogue. With projects in multiple issue areas, BPC combines politically balanced policymaking with strong, proactive advocacy and outreach.

This document contains small corrections and clarifications to the white paper originally published on February 4, 2014. This correction is effective as of February 18, 2014.
Substantial changes in energy markets, persistent challenges in courts, and difficulties in the implementation of relevant enacting laws have kept the Renewable Fuel Standard (RFS) at the forefront of energy policy discussions. There are both strong advocates in support of holding firm on the existing requirements and calls for outright repeal. But there also exists an active middle ground focusing on reforming, not repealing, the RFS.

The Bipartisan Policy Center (BPC) is undertaking a yearlong effort aimed at fostering constructive dialogue and action on reforming the RFS. To do this, BPC is convening a diverse RFS advisory group to discuss opportunities for reform, hosting public workshops to solicit broad input, and ultimately publishing viable policy options based, in part, on the advisory group’s deliberations.

As part of this effort, BPC has commissioned a series of background papers on various RFS topics. These papers are targeted at a broad audience that includes not only BPC’s advisory group, but also policymakers, industry, and the public, with the intention of educating and informing the wider debate surrounding this issue. Given a topic as complex as the RFS, these papers cover multiple issues, providing a focused view from the perspectives of technology, infrastructure, policy, and law. The first three background papers listed will be released in early February. The remaining two, which are two separate law firms’ perspectives on the same topic, will be released by the end of February.

1. **Technical Barriers to the Consumption of Higher Blends of Ethanol**  
   *The International Council on Clean Transportation*

2. **Petroleum and Renewable Fuels Supply Chain**  
   *Stillwater Associates LLC*

3. **Inventory of Federal Regulations Affecting Biofuels other than the Renewable Fuel Standard**  
   *Van Ness Feldman*

4. **The Environmental Protection Agency’s Authority to Amend the Renewable Fuel Standard**  
   *Sutherland Asbill & Brennan LLP*

5. **The Environmental Protection Agency’s Authority to Amend the Renewable Fuel Standard**  
   *Bracewell & Giuliani LLP*

BPC is releasing these papers as they were presented to us. The findings and opinions expressed in these background papers are solely those of the author(s). BPC takes no position on the findings nor conclusions developed in these papers, and they do not necessarily represent the views of BPC staff or the RFS advisory group.

To read other background papers in the series or for additional information about this effort, please visit [http://bipartisanpolicy.org/projects/energy/renewable-fuel](http://bipartisanpolicy.org/projects/energy/renewable-fuel).
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Executive Summary

To understand how complex federal policies like the Renewable Fuel Standard (RFS) impact market participants and consumers, a basic understanding of the petroleum and renewable fuels supply chain is required. This report is a primer of the transportation fuels distribution system and the federal mandates that guide it. It describes the individual supply chains for each of the three main transportation fuels—finished petroleum products (including gasoline and diesel), ethanol, and biodiesel—and where these fuels come together to be blended for retail use. A complex system of pipelines, rail, barges, and tanker trucks deliver these products to the end user.

Fuel-producing facilities are located in different parts of the United States. Refineries manufacturing finished petroleum products are largely concentrated on the Gulf and the East and West Coasts. Ethanol production facilities are mainly located in the Midwest. And biodiesel facilities are dispersed around the country. All of these fuels come together at the bulk storage and blending terminal so that they may be blended for retail use.

Bulk storage and blending terminals receive deliveries of finished petroleum products from refineries via pipeline and barge, with smaller deliveries arriving by tanker truck. Ethanol deliveries arrive in large part via rail, tanker truck, or barge. Biodiesel is supplied via rail or truck. At the storage and blending terminal, ethanol is blended with gasoline to create ethanol blends of E10 (10 percent ethanol), E15 (15 percent ethanol), or E85 (51 to 83 percent ethanol). Biodiesel is blended with petroleum diesel to create a variety of retail biodiesel blends, including B5, B10, and B20 (5 percent, 10 percent, and 20 percent biodiesel, respectively). Tanker trucks pick up the retail blends of finished product to deliver to retail outlets.

The RFS plays a significant role in the transportation fuels supply chain. The RFS mandates that gasoline sold in the United States be blended with renewable fuels and establishes advanced biofuel categories based on the degree of greenhouse gas (GHG) reduction. Obligated parties under the RFS are firms that supply gasoline and diesel to the domestic market, including refiners, importers, and gasoline blenders, and are required to blend renewable fuels into their finished petroleum products at a level that is determined annually by the U.S. Environmental Protection Agency (EPA). This is the Renewable Volume Obligation (RVO).

Renewable Identification Numbers (RINs) are the currency of the RFS and the method with which EPA keeps track of the RVO. RINs are discussed in terms of the code that identifies their renewable fuel category, also known as D Codes. D code 3 and 7 RINs are for cellulosic biofuels (i.e., fuels derived from cellulosic biomass like crop residue, switch grass, or tree residue). D4 RINs are biomass-based diesel, primarily biodiesel. D5 RINs are Advanced
Biofuels, and D6 RINs are Renewable Biofuels. Most of the volume in D5 is sugar cane ethanol from Brazil, and D6 RINs are generally associated with corn ethanol.

RINs are generated when renewable fuels are shipped from their manufacturing plant. These RINs are then “detached” when the renewable fuel is blended with gasoline or diesel at the distribution facility. The party holding the detached RIN can continue to hold it (for compliance) or sell it into the market. RINs are traded over-the-counter via commodities brokers or directly between buyers and sellers, and the prices are tracked and reported by pricing services. RIN prices were volatile in 2013. D6 (corn ethanol) RIN prices rose from about 7 cents per gallon at the beginning of the year to $1.00 per gallon in late February and then to $1.40 per gallon in July. RINs stayed high until the summer when EPA signaled that they were going to change the 2013 RVO.

One of the implementation challenges with the RFS is the ethanol “blend wall.” The Blend Wall is point at which ethanol blending, as mandated by the RFS, exceeds E10. At some point, increased ethanol volume requirements will be satisfied only by blending at levels above 10 percent ethanol or by increasing gasoline demand. However, gasoline demand has actually decreased due to the economic slowdown, and better fuel economy has compounded the problem. At the same time, blending higher concentrations of ethanol comes with a host of challenges, including service station liability if consumers misfuel with E15 and the need to upgrade existing infrastructure for higher ethanol blends. Automakers are concerned that use of E15 on older model vehicles will invalidate the warrantee. EPA has been reluctant to grant waivers to the Clean Air Act to allow summertime blending of E15 in areas that use conventional gasoline. Finally, consumer acceptance of E85 has been relatively slow, especially outside of the Midwest, where E85 fueling infrastructure is lacking. In all, the blend wall is when saturation of the E10 market creates a barrier to accommodating additional ethanol supply.

The RFS faces other challenges, including the level of cellulosic ethanol production that has failed to meet the goals set by the EPA. Cellulosic ethanol blending was forecast to reach one billion gallons by 2013, according to EPA’s initial RFS requirements. However, because cellulosic ethanol has yet to be produced on a commercial scale, that requirement was revised down to 17 million gallons for 2013. EPA anticipates they will have to revise the 2014 requirement as well.

Finally, the sale of fraudulent RINs has raised the cost of compliance for Obligated Parties. EPA has put measures in place to assure the quality of RINs, but these measures add administrative costs to the program.
Transportation Fuels Manufacturing

Petroleum Refining Centers

There are 139 operating petroleum refineries in the United States with a total production capacity of 17.8 million barrels per day.¹ The largest concentration of petroleum refining activity is in the Gulf of Mexico region, with 18 sites in Louisiana and 26 in Texas. In the Midwest, Illinois, Indiana, and Kansas account for seven sites. The West Coast has 14 refineries in California and five in the State of Washington. The East Coast has ten total with six in New Jersey, three in Pennsylvania, and one in Delaware.²

Figure 1. U.S. Petroleum Refinery Locations

Petroleum refineries range in crude oil processing capacity from 2,000 barrels per day (kbd) to more than 500 kbd, with an average capacity of about 140 kbd.³ This is equivalent to about 2.1 billion gallons per year (bgy).

Ethanol Manufacturing Centers

There are 193 operating ethanol facilities in the United States with a total production capacity of 13.9 billion gallons per year⁴ or about 900 kbd. This production is primarily produced from starch-based crops such as corn. According to the National Corn Growers Association, ethanol producers used 4.5 billion bushels of U.S. grown corn as ethanol feedstock in 2012. That accounts for about 40 percent of the total corn yield in 2012.⁵ In that year, the United States produced 13.3 billion gallons of ethanol.⁶ Much of that
production is concentrated in the Midwest because of its proximity to corn growers. The largest concentration of ethanol facilities is in Iowa. There are 41 ethanol plants in Iowa with a production capacity of 3.6 bgy.7

Ethanol production facilities range in capacity from 1.5 million gallons per year (mgy) to 200 mgy with an average capacity of about 70 mgy (5 kbd).8

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**Figure 2. U.S. Ethanol Facility Locations**

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**Biodiesel Manufacturing Centers**

There are 111 biodiesel facilities in the United States with a production capacity of two billion gallons per year. There is a prevalence of biodiesel facilities in the Midwest, but because biodiesel can be made from a variety of feedstocks, production facilities are not limited to areas where corn or soybeans are grown. Texas has the most facilities and the largest production capacity, producing 0.4 bgy from 13 facilities.9

Biodiesel production facilities range in capacity from 300,000 gallons per year to 100 mgy, with an average capacity of about 20 mgy (1.3 kbd).10
Biodiesel is derived from vegetable oil, animal fat, or waste oil. In 2012, the United States produced one billion gallons of biodiesel from seven billion pounds of feedstock. Soybean oil is the largest biodiesel feedstock with more than four billion pounds used for production in 2012.\textsuperscript{11}

**U.S. Feedstock Inputs to Biodiesel Production, 2012**

<table>
<thead>
<tr>
<th>FEEDSTOCKS</th>
<th>QUANTITY (MILLION POUNDS)</th>
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<tr>
<td>Vegetable Oils</td>
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<tr>
<td>Canola Oil</td>
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<td>Corn Oil</td>
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<td>Soybean Oil</td>
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<td>Animal Fats</td>
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<td>Other</td>
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<tr>
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<tr>
<td>Alcohol</td>
<td>607</td>
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<tr>
<td>Catalysts</td>
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</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7,318</strong></td>
</tr>
</tbody>
</table>

*Source: EIA*
Other Renewable Fuels

DROP-IN FUELS
Drop-in fuels are developed from bio-feedstocks, but are chemically identical to petroleum fuels and thus meet the American Society for Testing and Materials (ASTM) standard for on-road diesel and gasoline. As such, it can either be blended with or entirely replace petroleum diesel or gasoline without requiring any changes to fuel distribution infrastructure. Drop-in renewable diesel has a higher energy content and better cold weather performance compared with biodiesel. While biodiesel and renewable diesel use the same feedstocks, the differences between biodiesel and renewable diesel are the technologies used to make each fuel and the molecular content that is produced. Biodiesel is produced via transesterification, which results in fatty acid methyl esters (FAME). Renewable diesel is made via hydroprocessing, resulting in a high-quality fuel identical to petroleum diesel. Renewable diesel supplies have recently come onto the market in small but commercial-scale quantities.

Fuel producers are experimenting with production processes using second-generation feedstocks for both biodiesel and renewable diesel, collectively including such options as jatropha, algae, camelina, and municipal solid waste. The development of production plants able to use these feedstocks, however, is still in the pilot or demonstration phases.

CELLULOSIC BIOFUELS
Cellulosic biofuels are produced from a wide variety of non-food-based feedstocks comprised of cellulose, hemicellulose, or lignin. Examples include crop residues, wood residues, dedicated energy crops such as switch grass, and industrial waste such as pulp waste from paper mills. Biobutanol is a cellulosic biofuel that can be blended with other fuels for use in conventional gasoline vehicles and is considered a drop-in fuel. Biobutanol can be used as an oxygenate and blended with gasoline in concentrations up to 11.5 percent by volume.\textsuperscript{12}

Small-scale pilot plants, which produce less than 10 mgy of fuel, have been able to produce cellulosic ethanol, but problems exist with the current technologies that need to be overcome before commercial-scale (producing more than 10 mgy) cellulosic ethanol production becomes viable. Due to these remaining technology challenges, there are not yet any commercial cellulosic ethanol plants operating in the United States.
Transportation Fuels Distribution

Transportation fuels are refined at the petroleum refinery or biofuel plant. From the refinery or plant, they are transported via pipeline, rail, barge, or truck to bulk storage and blending terminals around the country. These fuels are blended for end use. Common transportation fuel blends include gasoline with 10 percent ethanol (E10) or 51 to 83 percent ethanol (E85), and diesel with 5 percent biodiesel (B5) or up to 99 percent biodiesel (B99).

Figure 4. Transportation Fuels Distribution System

Petroleum Distribution

The petroleum refinery is where the downstream flow of finished product begins. Pipelines and barges are the major bulk movers of finished product to the bulk storage and blending terminals. Terminals range in size and capacity, and are located to support retail, commercial, and government customers. Petroleum tanker trucks transport finished product from terminals to retail outlets.
**Figure 5. Petroleum Distribution System**

**Source:** EIA

**PIPELINES, BARGES, AND TRUCKS**

Pipelines ship gasoline and diesel in batches with products following each other in sequence toward their destination at the bulk storage and blending terminal. Electric pumps push the product through the miles of line with booster pumps and use drag reducing agent (DRA) to increase speed of flow. Pipelines are the safest and most efficient means of transporting product based on volume, cost to operate, and failure rates. There are approximately 95,000 miles of domestic finished petroleum pipelines in the United States.\(^{13}\)

Barges operate mainly in coastal and inland waterways and may be self-propelled or moved by tugboat. Barges are used as an inexpensive means of transporting finished petroleum products from refineries to terminals.\(^{14}\) There are 3,300 coastal, Great Lakes, and river tank barges operating in the United States that transport petroleum products.\(^{15}\) Barges serve terminals in the Northeast, Midwest, and Gulf Coast. One barge can carry about 875,000 gallons of product.

According to the U.S. Department of Transportation Research and Innovative Technology Administration (RITA), 62 percent of finished petroleum products were moved via pipeline in 2008, the latest data available. From the same data, 27 percent of finished products were transported via water carrier. Smaller amounts of finished products are transported by truck—about 4 percent.\(^{16}\)

**BULK STORAGE AND BLENDING TERMINALS**

The terminal is the next link in the supply chain for refined product, detergent additives, and fuel ethanol. There are 1,400 bulk storage and blending terminals around the United States.\(^{17}\) Terminals receive gasoline product mainly by marine vessels or pipeline, with smaller amounts delivered by truck. East Coast terminals are primarily marine receipt terminals while the western U.S. terminals receive shipments by pipeline. The Midwest is supplied by both river barge and pipeline.
Petroleum bulk storage facilities receive the petroleum light products—such as gasoline, jet fuel, diesel fuel, kerosene, and heating oil—from the refineries where it is stored for distribution to retail, wholesale, commercial, and government customers. The light products are blended with additives as the truck is loaded. Gasoline additives include ethanol, and required Federal Trade Commission (FTC) marker dyes identify products by producers. Diesel fuels are blended with lubricity additives, kerosene, and Internal Revenue Service (IRS) marker dyes to identify off-road use, such as farm equipment and boats for taxation purposes. Detergent additives are supplied to the terminal by truck, while fuel ethanol is delivered primarily by rail or barge.

Terminals blend gasoline or Blendstock for Oxygenate Blending (BOB) with ethanol as the delivery truck is loaded. BOB is unfinished gasoline designed to meet retail specifications when blended with 10 percent ethanol. Electronic meters control the blending ratios and calculate the quantity of ethanol to be loaded. Existing systems are designed in most locations for a 10 percent ethanol injection rate. Loading ratios are easily programmed to suit all blends by simply making minor software changes and adding new product codes. The terminal operators are responsible for the accuracy and calibration of all systems including gasoline, BOB, ethanol, and detergent additives.

Terminals generally have multiple storage tanks and configure their service based on estimated market volumes.

Terminals can distribute gasoline via pipeline—such as the ExxonMobil East Providence terminal, which supplies an 81-mile pipeline to its satellite terminal in Springfield, MA—and through a truck loading rack.

**Truck Loading Facilities (Rack)**

The truck loading rack consists of intricate piping schemes, pumps, injection systems, and electronic metering. The electronic meter serves as the brain of the rack and functions through the use of electromagnetic identification cards. These cards are issued to rack customers and contain data that allows terminal entry, volume allocation, and pricing, as well as truck safety inspections and driver qualifications. Loading racks are organized by bays where loading arms use couplers to connect to the tanker truck. It is at the rack, where the final product is made using required additives. The additives are most commonly injected at the truck loading rack either sequentially, as the product enters the tank truck, or in one dose at the beginning of the loading process. The truck loading rate of gasoline and ethanol will vary, but levels can be as high as 1,000 gallons per minute (gpm). In some cases, additives are injected at the header of the pipe before product arrives at the loading rack.

**PETROLEUM TANK TRUCKS**

Petroleum tank trucks load their products at the bulk storage terminal. Once the product is loaded on the truck, the truck operator assumes responsibility for custody, quality, and safety of the product. It is the duty of the truck operator to ensure that a tank truck is properly loaded with correct ratios of ethanol and detergent additives. Product custody is
transferred to the retail or commercial site once the delivery to the designated storage tank is completed. The U.S. Department of Transportation (DOT) and EPA require bills of lading (BOL) to follow product to the final destination.

Petroleum tank trucks are regulated by federal and state Departments of Transportation, state and local licensing bureaus, and state environmental agencies. The truck operators (drivers) must have qualifications including a commercial driver’s license (CDL) with hazardous material endorsements and a Transportation Workers Identification Credential (TWIC). The Transportation Security Administration (TSA) issues the TWIC to truck operators. The truck is the conduit of products to the end user at retail, commercial, or government sites.

There are 100,000 petroleum tank trucks operating in the United States. Tank truck volumes vary by state because some states like New York and Michigan grant overweight permits that allow trucks to deliver as much as 14,000 gallons, while other states like Massachusetts and Rhode Island grant permits for lesser volumes of 10,000 gallons and 12,500, respectively. These overweight permits supersede the Federal Highway Administration (FHWA) permits of 80,000 lbs. gross vehicle weight that equates to approximately 9,100 gallons depending on the design of the truck.

Fueling Locations

RETAIL

The retail service station site is the last link in the distribution system. There are approximately 150,000 service stations in the United States. Service stations vary in size, but most will have at least four dispensers per island, specifically two cabinets with fueling nozzles on each side.

Figure 6. Retail Gasoline Dispenser

Source: Stillwater Associates
Each retail station includes a number of underground storage tanks (USTs) that hold gasoline, diesel, and ethanol blends. Generally, service stations have three to four USTs to store products.\(^1\)

Retail sites have evolved over the past two decades away from traditional automobile-focused operations to more retail convenient-store businesses offering grocery items and in many cases co-franchising with national brands like Subway or Dunkin Donuts.

**COMMERCIAL**
Commercial customers are end users such as construction or trucking companies. Most commercial customers use common trucking carriers to pick up and deliver product to their centrally located, company owned, fueling stations. Large commercial customers will operate and maintain limited storage at their fueling stations that include aboveground enclosed storage tanks ranging in size from three to five gallons at most.

**GOVERNMENT**
Federal, state, and local governments operate fueling facilities for public works and emergency vehicles. The fuels are supplied by the local bulk storage terminal and delivered using a common trucking carrier. The Department of Defense is the single largest consumer of petroleum-based fuels while at same time seeking to convert to more renewable alternatives.

**Ethanol Distribution**
Most ethanol plants are located in the Midwest where feedstocks for ethanol are grown. However, the biggest markets for ethanol are on the East Coast, California, and Texas, where large refining centers are located and where fuel consumption is the highest. Ethanol producers must transport their product long distances to the refining centers in these areas. Rail or tanker trucks transport the majority of ethanol. The remainder is transported by barge. Prior to shipment from the ethanol plant, 100 percent ethanol is blended with 2 percent petroleum, rendering it unfit for human consumption. This process is called denaturing and is performed in order to avoid liquor tax implications outlined by the Alcohol and Tobacco Tax & Trade Bureau (TTB).\(^2\) Denaturing creates 98 percent ethanol or E98. All ethanol transported from the ethanol facility is E98.
The American Rail Association estimates that 70–75 percent of ethanol produced in the ethanol facility is transported by rail.\textsuperscript{20} All seven U.S. Class I freight railroads transport ethanol. Class I railroads are defined as having annual carrier operating revenues of at least $433.2 million or more. These include BNSF Railway, CSX Transportation, Grand Trunk Corporation, Southern Combined Railroad Subsidiaries, Soo Line Railroad, and Union Pacific Railroad.\textsuperscript{21} About 15 to 20 percent of ethanol rail movements originate on non-Class I railroads, which are rural, short rail lines adjacent to production facilities. Ethanol moved by rail is carried in 30,000-gallon tank cars. Generally, these cars are owned by shippers or leasing companies, not the railroads. In 2012, 311,000 carloads of ethanol were moved by rail.\textsuperscript{22}

A tanker truck can carry 8,000 to 10,000 gallons of ethanol, while one rail car can carry approximately 30,000 gallons of ethanol. Tanker trucks are used for shorter distances in the supply chain. About 20 percent of ethanol is transported from the ethanol facility via truck.\textsuperscript{23} Trucks also carry grain from the growers to the ethanol production plants. From the ethanol production plants, trains, barges, and trucks haul ethanol to petroleum bulk storage terminals. The consumer blends are made at the truck loading rack in the petroleum bulk storage terminal with the exception of E98, which is blended with petroleum products at the ethanol plants and shipped in 55-gallon drums. Tanker trucks, exclusively, haul E10 and E85 from petroleum storage terminals to retail outlets.

As with petroleum products, barges deliver ethanol to distribution centers in the Midwest, South, and the Northeast via rivers, the inter-coastal waterway, and lakes. About 10 percent of ethanol from ethanol facilities is transported via barge.\textsuperscript{24}
Delivering ethanol by pipeline is an option, but ethanol’s affinity for water and solvent properties requires use of a dedicated pipeline or the significant cleanup of existing pipelines. Kinder Morgan Pipeline ships batches of ethanol through its Central Florida Pipeline and is evaluating shipping ethanol in its Plantation Pipeline.

**Biodiesel Distribution**

Biodiesel is distributed from the point of production to fuel distributors and wholesalers by truck, train, or barge. Biodiesel is generally blended with petroleum diesel with the most popular blends at 5 percent biodiesel (B5) or 20 percent (B20).

*Figure 8. Biodiesel Distribution*

As with ethanol distribution, most biodiesel is transported by rail to refining centers on the East and West Coasts. However, 100 percent biodiesel (B100) sometimes must be transported in insulated and heated cars to avoid solidifying in cold weather. Tanker trucks carry biodiesel shorter distances from the production plant to petroleum bulk storage terminals. Tanker trucks are the only means for delivering biodiesel to the retail outlets.

**Other Renewable Fuels**

The volume of other renewable fuels such as cellulosic ethanol and drop-in gasoline and diesel are so small that modes of distribution have yet to become an issue. However, cellulosic ethanol faces the same storage and distribution constraints as conventional ethanol and must be distributed in the same manner. Drop-in fuels by definition do not require any adjustment to the existing distribution system.
Ethanol and Biodiesel Blends

Renewable Fuels Definitions

<table>
<thead>
<tr>
<th>FUEL</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>Ethanol</td>
<td>A renewable fuel derived from biomass such as corn or sugarcane.</td>
</tr>
<tr>
<td>E10</td>
<td>A low-level ethanol blend comprised of 10 percent ethanol and 90 percent gasoline. E10 is the most common ethanol blend sold in the United States.</td>
</tr>
<tr>
<td>E15</td>
<td>A low-level ethanol blend comprised of 15 percent ethanol and 85 percent gasoline. The EPA has recently approved E15 for use in cars model year 2001 and younger.</td>
</tr>
<tr>
<td>E85</td>
<td>A high-level ethanol blend comprised of 51-83 percent ethanol. E85 is approved for use only in Flexible Fuel Vehicles (FFVs).</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>A renewable fuel derived from biomass such as vegetable oils, animal fats, or waste grease</td>
</tr>
<tr>
<td>B5</td>
<td>A low-level biodiesel blend comprised of 5 percent biodiesel and 95 percent petroleum diesel. B5 is the most common biodiesel blend sold in the United States.</td>
</tr>
<tr>
<td>B20</td>
<td>A higher-level biodiesel blend comprised of 20 percent biodiesel and 80 percent petroleum diesel. Most diesel car and truck manufacturers selling in the United States warrantee their vehicles for B20 use.</td>
</tr>
<tr>
<td>B100</td>
<td>100 percent biodiesel is less commonly available than lower blends of biodiesel. B100 can be used in diesel engines built since 1994 with biodiesel compatible parts.</td>
</tr>
<tr>
<td>Drop-in Fuels</td>
<td>Fuels derived from bio-feedstocks that are chemically identical to conventional gasoline or diesel. Drop-in fuels are engineered to be blended with or replace petroleum fuels without any changes to the fuel infrastructure.</td>
</tr>
<tr>
<td>Renewable Diesel</td>
<td>Diesel fuel derived from biomass and refined via hydroprocessing. This refining process results in a fuel chemically identical to petroleum diesel.</td>
</tr>
<tr>
<td>Cellulosic Biofuels</td>
<td>Fuels derived from non-food-based biomass such as crop residue or switch grass. Biobutanol is a cellulosic biofuel that can be blended with other fuels and used in conventional gasoline vehicles.</td>
</tr>
</tbody>
</table>

Ethanol

**E10**

E10 is a low-level blend composed of 10 percent ethanol and 90 percent gasoline. EPA classifies it as "substantially similar" to gasoline and is legal for use in any gasoline-powered vehicle. The use of E10 was spurred by the Clean Air Act Amendments of 1990 (and subsequent laws), which mandated the sale of oxygenated in areas with unhealthy levels of carbon monoxide. This kicked off the modern U.S. ethanol industry growth. Today, E10 is
sold in every state. In fact, more than 95 percent of U.S. gasoline contains up to 10 percent ethanol to boost octane, meet air-quality requirements, or satisfy the Renewable Fuel Standard (RFS).

The fuel distribution and consumption supply chain is tailored to handle E10. This includes refinery operations, terminal blending, service station configuration, and automobile design. The point at which ethanol blending, as mandated by the RFS, exceeds E10 is called the "blend wall." The blend wall is when saturation of the E10 market creates a barrier to accommodating additional ethanol supply. More discussion of the blend wall appears in Section 4 of this report.

**E15**

E15 is a low-level blend composed of 15 percent ethanol and 85 percent gasoline. In 2011, EPA approved E15 for use in model year 2001 and newer conventional vehicles. There are several EPA requirements and regulations that stations must adhere to when selling E15. The most significant requirements are implementation of a misfueling mitigation plan and registration for an annual fuel survey. (Misfuelling is a concern for conventional vehicles older than model year 2001.) E15 helps to meet the federal RFS.

**OTHER MID-LEVEL ETHANOL BLENDS**

Federal and local initiatives to increase the use of ethanol in transportation have resulted in an increase in new ideas and applications for flexible-fuel vehicles (FFVs). One option is the ethanol blender-pump dispenser. Blender pumps draw fuel from two separate storage tanks (E10 and E85) and can dispense preprogrammed blends of those two fuels. Blender pumps offer FFV owners a variety of ethanol-blended gasoline products between E15 and E85. E20 (20 percent ethanol, 80 percent gasoline) and E30 (30 percent ethanol, 70 percent gasoline) are the most common blends selected. Stations offering blender-pump blends to FFV owners are concentrated in the Midwest. Blender pumps are also a legal method to dispense E15 to conventional vehicles of model year 2001 and newer. Labels must clearly indicate blender pump fuels for FFVs.

**E85**

E85 is a high-level gasoline blend containing 51 percent to 83 percent ethanol, depending on geography and season. E85 can be used in FFVs, which have an internal combustion engine and can run on E85, gasoline, or any blend of the two. E85 cannot be legally used in conventional gasoline-powered vehicles. FFVs are similar to conventional vehicles, but are engineered to run on gasoline blends up to E85. According to the EIA, there are eight million FFVs owned in the United States—about 3 percent of the U.S. fleet. One of the problems with running on higher ethanol blends like E85 is lower fuel economy. E85 is 27 percent less energy dense than conventional gasoline. FFVs offer lower mileage while running on E85 than vehicles that run on conventional gasoline, and users must fill up more often. Because E85 users need to fill up more often, E85 would need to be priced at a discount to gasoline so that drivers can achieve the same mileage per dollar. This is referred to as energy parity.
Retail service stations offering E85 make up about 2 percent of all service stations in the United States. Most of the 2,388 stations are located in the Midwest. Consumer acceptance of E85 outside of the Midwest has been slow. Even when E85 is priced at parity with regular gasoline, consumers must fill up more often. The lack of E85 infrastructure outside the Midwest makes E85 stations hard to find.
Biodiesel

**B5**
Blends of up to 5 percent biodiesel (B5) are legally categorized as diesel fuel, eliminating any operational or potential warranty concerns. B5, when properly handled, will perform just like diesel. Most vehicle manufacturers approve blends up to B5.

**HIGHER-LEVEL BLENDS**
B20 (20 percent biodiesel, 80 percent petroleum diesel) represents a good balance of cost, emissions, cold-weather performance, materials compatibility, and ability to act as a solvent. Nearly 80 percent of diesel vehicle manufacturers selling in the United States warranty their cars and trucks for B20 use, including Ford’s 2013 F-Series Super Duty Truck and Chrysler’s 2013 Ram Heavy Duty Pickup. Using B20 provides substantial benefits and avoids many of the cold-weather performance and material compatibility concerns associated with B100. However, not all diesel engine manufacturers cover biodiesel in their engine warranties. Users must consult their owner’s manual before fueling with a biodiesel blend. Most biodiesel users purchase B20 or lower blends from their petroleum distributors or biodiesel marketers. Biodiesel blends of B20 or higher qualify for biodiesel fuel-use credits under the Energy Policy Act of 1992.²⁸

B100 and other high-level biodiesel blends are less common than B5 or B20 due to a lack of regulatory incentives and pricing. B100 can be used in some engines built since 1994 with biodiesel-compatible material for parts, such as hoses and gaskets. B100 has a solvent effect and it can clean a vehicle's fuel system and release deposits accumulated from previous petroleum diesel use. The release of these deposits may initially clog filters and require filter replacement in the first few tanks of high-level blends.²⁹
Renewable Fuel Standard (RFS)

The original RFS was part of the Energy Policy Act of 2005 ("EPAct05") passed by the 109th Congress and was signed by President Bush on August 8, 2005, becoming Public Law 109-58 section 211 (o) of the Clean Air Act (CAA). It mandated that gasoline sold in the United States contain a minimum amount of renewable fuel.

The Energy Independence and Security Act of 2007 passed by the 110th Congress was signed by President Bush on December 19, 2007, and became Public Law 110-140 to establish the Renewable Fuel Standard—2 (RFS2). It greatly increased the conventional ethanol and conventional biodiesel mandate and established advanced biofuel categories based on the degree of greenhouse gas (GHG) reduction.

The Currency of the RFS is the RIN

Each gallon of renewable fuel is assigned a Renewable Identification Number (RIN) when the fuel is shipped from its manufacturing plant. The RIN is a 38-digit number that describes the type of renewable fuel, year of production, company identification, and other relevant information. The owner of the renewable fuel controls the RIN at this stage. RINs are valid in the calendar year they are generated and the following calendar year. A RIN expires after two years.30

RINs are discussed in terms of the code that identifies their renewable fuel category, also known as D Codes. D code 3 and 7 RINs are for cellulosic biofuels (i.e., fuels derived from cellulosic biomass, like crop residue, switch grass, or tree residue). D4 RINs are biomass-based diesel, primarily biodiesel. D5 RINs are Advanced Biofuels, and D6 RINs are Renewable Biofuels. Most of the volume in D5 is sugar cane ethanol from Brazil, and D6 RINs are generally associated with corn ethanol.
Refiners, Importers, and Gasoline Blenders are Obligated Parties Under the RFS

Firms that supply gasoline and diesel to the domestic market are obligated to blend renewable fuels into their fuels at a level that is annually determined by the EPA. This is the Renewable Volume Obligation (RVO). Each D Code has an RVO. As a percentage of gasoline and diesel production, the 2013 RVO was:

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3 and D7 Cellulosic Biofuel</td>
<td>0.004</td>
</tr>
<tr>
<td>D4 Biomass-Based Diesel</td>
<td>1.130</td>
</tr>
<tr>
<td>D5 Advanced Biofuel</td>
<td>1.620</td>
</tr>
<tr>
<td>D6 Renewable Fuel</td>
<td>9.740</td>
</tr>
</tbody>
</table>

RINs are nested so that:

- D3 and D7 Cellulosic Biofuel RINs can also be applied toward the D4, D5, and D6 mandates. However, there is very little Cellulosic Biofuel production.
- Biomass biodiesel D4 RINs can also be applied toward the D5 and D6 mandates (with D5 RINs applicable toward the D6 RIN requirement).
- RINs generated from additional blending of biomass-based diesel and advanced biofuels can be counted toward the D6 RIN mandate.
- Obligated parties that are short D6 RINs can buy D4 or D5 RINs to meet their RVO.

**Figure 11. 2013 Renewable Volume Obligation**

*Source: Stillwater Associates*
Obligated Parties are required to demonstrate to EPA compliance with the RFS by acquiring RINs equivalent to the RVO times the volume of gasoline and diesel that they produce and sell in the United States.

For example, an Obligated Party who produces 100 million gallons of gasoline and diesel sold in the United States would have to submit to the EPA the following number of RINs:

<table>
<thead>
<tr>
<th>Category</th>
<th>RINs</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3 and D7 Cellulosic Biofuel</td>
<td>4,000</td>
</tr>
<tr>
<td>D4 Biomass-Based Diesel</td>
<td>1,130,000</td>
</tr>
<tr>
<td>D5 Advanced Biofuel</td>
<td>1,620,000</td>
</tr>
<tr>
<td>D6 Renewable Fuel</td>
<td>9,740,000</td>
</tr>
</tbody>
</table>

RINS ARE SEPARATED FROM THE FUEL AT THE POINT OF BLENDING

When the renewable fuel is blended with the petroleum fuel, the RIN is separated from the renewable fuel and is the property of the firm who owned the renewable fuel at the time of blending.

The RIN holder has three options at this stage. First, if the holder of the RIN is an Obligated Party, he can retain the RIN and use it to demonstrate compliance with the RVO. Second, some Obligated Parties generate more RINs than needed for the RVO, so these parties can retain the RIN to use later. The third option is to sell the RINs into the RIN market.

In many cases, Obligated Parties sell their gasoline and diesel upstream of the distribution terminal and are not in the supply chain when the blending occurs. Therefore, not all RINS are separated by Obligated Parties. If a distributor or jobber31 (who is not an Obligated Party) blends the renewable fuel with the petroleum, then the RIN is owned by that distributor or jobber. They can sell the RIN into the market or retain it for sale in a later period. Obligated Parties will buy the RINs separated by the distributor or jobber in order to demonstrate compliance with their RVO.

Renewable Identification Numbers Trading

The sellers of RINs are Obligated Parties who have more RINs than they need or non-Obligated Parties who have separated RINs through their normal business of blending renewable fuels and petroleum fuels. RINs buyers are Obligated Parties who need more RINs than their blending business separates. Other market participants include commodity-trading companies who may buy and sell RINS.

RINs are traded over-the-counter through commodities brokerages or directly between buyers and sellers. D3 RINs have not traded because there is little or no commercial scale production of cellulosic ethanol and buyers have retained these RINs for their RVO.

RINs prices are tracked and reported by pricing services such as Argus, Platts, PFL, and the Oil Price Information Service (OPIS). The services obtain the pricing data by surveying market participants about the trades the participants made during a day.
MARKET PRICE HISTORY

Focusing on the high-volume D6 RINs, these traded at values of around 3 cents per gallon (cpg) until late in 2012 when the market doubled to 6 to 7 cpg. The market then rapidly rose to $1.00 per gallon in late February 2013 and then to $1.40 per gallon in July. RINs stayed high until the summer, when EPA signaled that they were going to change the RVO.

The first price spike occurred as Obligated Parties began to realize that they had to submit to the EPA their end-of-the-year reports on the RVO. Obligated Parties who lacked enough RINs had to go to the market to buy the volume needed to demonstrate compliance. Obligated Parties who had spare RINs were reluctant to sell, fearing higher prices later. With almost all gasoline blended with 10 percent ethanol (E10), and higher-level ethanol blends with small market share, the volume of ethanol hit the E10 “blend wall” as demonstrated by the spike in D6 RINs prices. Obligated parties could not separate or buy enough D6 RINs to meet their RVO.

D4 and D5 RINs generally moved in tandem with, and slightly higher than, D6 RINs after the February spike because they can be used to meet the D6 RVO once their own RVOs are satisfied.

![Figure 12. 2013 Corn Ethanol (D6) RIN Spot Prices](image)

*Source: OPIS*

MARKET RESPONSES TO HIGH RINS PRICES

When RINs prices get very high, Obligated Parties will look to reduce their exposure to the RINs market. They have a number of choices. The first is to move downstream and acquire more customers who need blended fuels. Note that this tactic shifts the separation of the
RIN onto an Obligated Party but does not create any additional RINs, because the same amount of renewable fuel is blended. However, many refiners have left the wholesale and gas station markets and no longer have the outlets needed to take renewable fuels blended product.

When RINs prices were high, E85 became more interesting because additional ethanol blending generated RINs, improving the economics of E85. The RINs boom was short lived, and it is unclear how many service station owners invested in E85 in that time frame.

A second choice refiners have is to not make as much gasoline and diesel as they might otherwise make. This would include producing more jet fuel at the expense of gasoline and diesel. Refiners have some flexibility to shift between gasoline, jet, and diesel production. Jet fuel is not subject to this regulation. Refiners also could decide to not process as much crude oil as they might otherwise process, reducing production of gasoline, diesel, and the rest of their slate of products.

Refiners also can export gasoline and diesel because the exported volume does not have an RVO.

Importers can stop importing fuel because the cost of RINs is so high as to compel those firms to send their products to some other country.

These last options help to explain EPA’s proposal to revise the RVO to below the blend wall. Obligated Parties may be forced to reduce supply of gasoline and diesel in order to comply with the regulation.

What are the Implementation Challenges with the RFS?

THE “BLEND WALL”
The main challenge with the RFS is that the volume of ethanol has reached 10 percent of gasoline. The decrease in gasoline demand due to the economic slowdown and better mileage have compounded the problem. Increased ethanol volume requirements can be satisfied only by blending at levels above 10 percent or by increasing gasoline demand.

There are other challenges as well. Service station owners are concerned about their liability if consumers misfuel by using E15 in a car that is only designed for E10. They are also concerned about using their existing equipment (tanks, lines, pumps, and dispensers) in E15 service when they are certified for a maximum ethanol content of E10.32 Retrofitting their equipment is likely to cost from $20,000 to $100,000 per station.

On the auto side, E10 is the maximum amount that most auto manufacturers will warrant the performance of their cars built after 2001. According to the EPA, these later model cars can safely use E15, but automakers are concerned about the prior warranties. Use of E15
could invalidate the warrantee. A number of automakers do warrantee the use of E15 in their new cars.

Additionally, EPA has been reluctant to grant waivers to the Clean Air Act to allow summertime blending of E15 in areas that use conventional gasoline. Eighteen states have regulations that cap ethanol content at 10 percent of gasoline.\footnote{33}

Because of service station restrictions, automobile constraints, and limited acceptance of E85, there is no clear path to the development of a supply chain to support consumption of ethanol at levels greater than 10 percent.

**PRODUCTION OF CELLULOSIC ETHANOL HAS FAILED TO MEET THE GOALS SET**

Cellulosic ethanol blending was forecast to reach one billion gallons by 2013, according to EPA’s initial RFS requirements. EPA’s 2013 RVO for cellulosic ethanol is six billion gallons but the forecasts are for much less than that.\footnote{34} Several commercial-scale cellulosic ethanol plants are scheduled for start-up in 2014.\footnote{35} EPA’s proposed RVO for cellulosic ethanol for 2014 is 17 million gallons. Cellulosic ethanol volumes will have to compete with corn and sugar cane ethanol volumes for space under the cap of the blend wall. Presumably, D3 RINs prices will be high enough for cellulosic ethanol to be competitive with the other ethanols.

**FRAUDULENT RINS HAVE RAISED THE COST OF COMPLIANCE**

Starting in 2011, market participants began to realize that millions of RINs were being fraudulently created. Three companies were issued notices of violation of the RFS, and several owners of the issuing companies were convicted of fraud.\footnote{36} Obligated Parties who bought the fraudulent RINs had to buy replacement RINs. They were fined by the EPA for failing to meet the RVO because some of the RINs were fraudulent.

In order to address the fraudulent RINs issue, the EPA has proposed a new voluntary quality assurance program to be used by RINs purchasers in order to ensure the RINs in the market are valid.

“On January 31, 2013, the EPA issued a Notice of Proposed Rulemaking (NPRM) that proposed amendments to the RFS regulations. The NPRM set forth minimum requirements for a voluntary program to implement structured quality assurance plans (QAPs), and proposed to create an affirmative defense against civil liability arising from the transfer and use of invalid RINs that were verified under a QAP. In order to encourage the development and use of QAPs as soon as possible, the NPRM includes a proposal to allow parties to retrospectively verify RINs that are generated in 2013. The EPA is implementing a Second Interim Enforcement Response Policy in order to encourage early implementation of independent third party QAPs.”\footnote{37}

In order to create an affirmative defense, RINs buyers have two options, both adding administrative costs to the program. In both options the RINs buyer purchases RINs through a third-party auditor. The first option is to buy RINs from an auditor that has verified the RINs via the rigorous EPA approved QAP. With this option, the auditor is responsible for replacing any RINs that are found to be invalid. The second option is to buy
RINs from an auditor that has verified the RINs using a less rigorous QAP. In this case, the RINs buyer would be responsible for any RINs found to be invalid, but they would have an affirmative defense to an enforcement action if they could establish that they did not know that the RIN was invalid at the time it was sold or retired.38
**ASTM International**
A nonprofit organization that develops and delivers international standards. ASTM standards, test methods, specifications, and procedures are recognized as definitive guidelines for fuel quality.

**Blendstock for Oxygenate Blending**
Unfinished gasoline designed to meet retail specifications when blended with 10 percent ethanol.

**Biodiesel**
Fuel produced from vegetable oils (such as oilseed, rapeseed, and soya bean), animal fats, or algae. Biodiesel can be blended with diesel for use in diesel engine vehicles.

**Biomass**
Plant matter such as trees, grasses, agricultural residue, algae, and other biological material.

**Blender Pump**
A fuel dispenser that draws fuel from two separate storage tanks and can dispense preprogrammed blends of those two fuels.

**Blend Wall**
Occurs when saturation of the E10 market creates a barrier to accommodating additional ethanol supply.

**Bulk Storage and Blending Terminal**
A facility used primarily for the storage and/or marketing of petroleum products, which has a total bulk storage capacity of 50,000 barrels or more and/or receives petroleum products by tanker, barge, or pipeline.

**Class I Freight Railroad**
Defined by the Interstate Commerce Commission each year based on annual operating revenue. A railroad is dropped from the Class I list if it fails to meet the annual earnings threshold for three consecutive years.

**Denatured**
Fuel ethanol that is rendered unfit for human consumption by the addition of a petroleum denaturant, typically pentanes plus or conventional motor gasoline. Fuel ethanol is usually denatured prior to transport from the ethanol production facility.

**Ethanol**
Otherwise know as ethyl alcohol, alcohol, or grain-spirit. A clear, colorless, flammable
oxygenated hydrocarbon with a boiling point of 78.5 degrees Celsius in the anhydrous state. In transportation, ethanol is used as a vehicle fuel by itself, blended with gasoline, or as a gasoline octane enhancer and oxygenate.

**Finished Petroleum Products**
A complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in spark-ignition engines.

**Feedstocks**
Any material converted to another form of fuel or energy product. An example is using cornstarch to produce ethanol.

**Greenhouse Gas**
Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

**Jobber**
A distributor, jobber, or petroleum marketer is a person or company that purchases refined fuel from refining companies to sell to retailers or direct to consumers. A jobber is essentially a middleman.

**Obligated Party**
Firms that supply gasoline and diesel to the domestic market are obligated to blend renewable fuels into their fuels at a level that is annually determined by the EPA.

**Oxygenate**
A cleaner-burning additive in a fuel—usually containing hydrogen, carbon, and oxygen. Examples are ethers and alcohols, such as ethanol and methanol.

**Petroleum Diesel**
Petroleum diesel used for transportation fuel, known as No. 2 Diesel Fuel, has a distillation temperature of 640 degrees Fahrenheit at the 90 percent recovery point and meets the specifications defined in ASTM Specification D 975. It is used in high-speed diesel engines, such as those in railroad locomotives, trucks, and automobiles.

**Renewable Fuel Standard (RFS)**

**Renewable Identification Numbers (RINs)**
Each gallon of renewable fuel is assigned a Renewable Identification Number (RIN) when the fuel is shipped from its manufacturing plant. The RIN is a 38-digit number that describes
the type of renewable fuel, year of production, company identification, and other relevant information.

**Renewable Volume Obligation (RVO)**
The volume of renewable fuel annually determined by the EPA that obligated parties are required to blend with gasoline and diesel for the domestic market.
Endnotes


2 Ibid.

3 Ibid.


10 Ibid.


16 RITA and Bureau of Transportation Statistics. National Transportation Statistics 2013. Table 1-61M.—Crude Oil and Petroleum Products Transported in the United States by Mode.

17 Ibid.


24 Ibid.


27 Ibid.


29 Ibid.

31 A distributor, jobber, or petroleum marketer is a person or company that purchases refined fuel from refining companies to sell to retailers or direct to consumers. A jobber is essentially a middleman.


35 Ibid.

36 Available at: http://www2.epa.gov/enforcement/civil-enforcement-renewable-fuel-standard-program.

37 Ibid.