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American Petroleum Institute

Impact of the Blend Wall Constraint in Complying with the Renewable Fuel Standard

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1 EXECUTIVE SUMMARY

The ethanol "blend wall" could constrain the amount of ethanol that can be blended in gasoline.

- The current Renewable Fuel Standard program (RFS2) requires that substantial volumes of renewable fuels be used in the transportation fuel sold in the United States and sets annual target volumes for the use of these fuels that increase steadily through 2022. As a practical matter, meeting these targets can only be achieved by increasing the average ethanol content of the fuels used to power cars and trucks.
- Successful implementation of the RFS2 program is threatened by the existence of an ethanol "blend wall" – the maximum concentration of ethanol that can be blended in gasoline and used by conventional gasoline-powered motor vehicles. A gasoline blend containing 10 percent ethanol by volume ("E10") is the only registered ethanol/gasoline fuel approved by EPA for use in conventional vehicles today.
- The steadily increasing volumes of ethanol fuel required to satisfy the RFS2 program's targets will eventually encounter the blend wall; i.e., at some point in the not too distant future, the program will effectively require that more ethanol be used than can be accommodated in gasoline blends containing no more than 10 percent ethanol.

When will the blend wall become binding?

- The American Petroleum Institute (API) retained Charles River Associates (CRA) to develop an independent assessment of when the RFS2 program will encounter the blend wall, i.e., to identify the first year in which the RFS2 program will effectively require that the ethanol content in the gasoline used by conventional gasoline-powered vehicles exceed 10 percent.
- CRA's independent assessment is that the blend wall will first be encountered in 2011, 2012, or 2013. This assessment is based on CRA's analysis, which applies the RFS2 program targets to annual fuel volume forecasts derived from the most recent Energy Information Agency (EIA) Annual Energy Outlook 2011 (AEO2011) reference case and High Oil Price case scenarios. In performing this analysis, CRA also considered the extent to which other strategies to increase the average renewable fuels content of transportation fuels might offset the need to blend more than 10 percent ethanol into motor gasoline.
- CRA's findings contrast with those presented in the Regulatory Impact Analysis prepared by the Environmental Protection Agency in support of the EPA's final RFS2 program rules. The EPA analysis concluded that the blend wall will first be encountered in 2013, 2014, or 2015. The differences between the EPA and CRA results are largely attributable to CRA's use of a more up-to-date forecast of future energy consumption and to CRA's adoption of certain assumptions about certain fuel substitution possibilities that are more up-to-date than those used in the now dated EPA analysis.

Practicably achievable changes in the sales volumes of "niche" fuels (E85, E15, E0, or biodiesel) are insufficient to postpone encountering the blend wall

- In theory, substantial increases in the consumption of certain "niche" fuels (E85, E15, E0, and biodiesel) might, by offsetting some of the volumes of ethanol that would otherwise have to be included in the gasoline used by conventional vehicles, help postpone the year in which the RFS2 program first encounters the blend wall. In reality, however, the measures that would be required to effect the necessary changes in the consumption of these fuels are not practicably achievable in the short time that remains between now and the year in which the blend wall will first be reached. We examined four measures – increasing consumption of high-ethanol gasoline blends (E85) for use in flex-fuel vehicles, introducing for sale a new gasoline blend containing 15 percent ethanol by volume (E15), eliminating or reducing sales of neat gasoline (E0), and increasing biodiesel volumes to levels well in excess of those that will effectively be mandated by the RFS program's biomass-based diesel standard. In each case, we identified substantial barriers that effectively prevent these measures from being implemented over the next few years on the scales that would be required to postpone encountering the blend wall. These barriers include issues of consumer acceptance, inadequate infrastructure, resource constraints, and the need to motivate non-obligated parties, like the owners of retail fuel stations, to make crucial investments in the absence of clear incentives for them to do so.

Economic consequences of reaching the blend wall

- Once the blend wall is reached, obligated parties will be left with only changes in fuel mix as viable paths to compliance. An obligated party's RFS2 compliance is not determined directly in accordance with the volumes of renewable fuels it has been able to incorporate into its slate of transportation fuels. Instead, annual compliance with the program's standards is measured by comparing the percentage of renewable fuels content in an obligated party's combined gasoline and diesel fuel pools to an annual percentage target established by EPA prior to the start of the year. As a result, obligated parties may be able to achieve compliance by taking actions to limit sales of fuels containing no or relatively little renewable fuels content, encourage the sale of fuels with relatively high renewable content, or both.
- Obligated parties would thus face incentives to reduce their sales of low-renewable content fuels like neat gasoline or diesel fuel and, despite a history of poor consumer acceptance, to increase their sales of fuels with relatively high renewable content, such as E85. The fuel used in conventional vehicles, E10, represents a special case. Obligated parties may choose to promote E10 sales in the earliest years of the RFS2 program, as one action that facilitates compliance. But the usefulness of this action is limited to years in which the targets for renewable content are relatively low – well under 10 percent, and this incentive will quickly reverse itself once percentage renewable fuels targets exceed 10 percent.
- As obligated parties adjust their production volumes in line with these incentives, the costs to consumers for low-renewable-content fuels can be expected to increase and the costs of higher renewable-content fuels should decrease relative to the levels that

would otherwise be expected to prevail in the marketplace. But even these actions are likely to prove effective for only a few years at most. As the renewable fuel volumes mandated under the RFS2 program increase, obligated parties will find even their ability to sell E10 limited by their ability to generate sales of higher-ethanol-content niche fuels. At such a point, achieving compliance will require obligated parties to cut their sales of conventional fuels to match their ability to sell volumes of higher-renewable-content niche fuels like E85. The result will be limited availability, higher consumer costs, and fewer sales of conventional transportation fuels. Eventually, the entire system could break down; creating conditions for a "death spiral" in which the volume of conventional fuels that can be sold legally will come to decrease precipitously from one year to another.

2 OVERVIEW OF FINDINGS

2.1 Introduction

The timing and consequences of motor gasoline reaching the ethanol "blend wall" are potentially critical concerns in implementing the Renewable Fuel Standard ("RFS2").[1] The ethanol "blend wall" refers to the maximum concentration of ethanol that can be blended in gasoline and used by conventional gasoline-powered motor vehicles. A gasoline blend containing 10 percent ethanol by volume ("E10")[2] is the only registered ethanol/gasoline fuel approved by EPA for use in conventional vehicles today. Therefore, the blend wall is breached when the mandated ethanol volume exceeds 10% of the gasoline pool. [3] Original equipment manufacturers design and warranty engines and vehicles consistent with the E10 specification. Flex-fuel vehicles (FFVs) are certified to use fuel blends containing up to 85 percent volume ethanol, or E85.[4] RFS2 requires ever-increasing volumes of renewable fuels to be blended in transportation fuels to 2022. At some point, these increases will require sufficiently high average ethanol content in the gasoline pool that the blend wall will become a binding constraint to the greater use of renewable fuels or, alternatively, force a reduction in availability of certain transportation fuels or all transportation fuels in general. Just when the blend wall will become constraining is a disputed and controversial subject. Estimates vary from that of the EPA, which claims the blend wall will not be reached until the 2013-2015 timeframe[5] to that of Wallace Tyner, Professor of agricultural economics at Purdue University, who asserts that the blend wall has already been reached.[6]

[1] RFS2 was legislated in the Energy Independence and Security Act of 2007.

[2] By convention, ethanol/gasoline blends are designated by the letter E followed by a number that represents the highest allowable volume of ethanol in the blend; hence E10 contains up to 10 percent ethanol by volume; E85 contains up to 85 percent ethanol blend stock by volume (up to 83 percent pure ethanol after taking into account the denaturant component of the blend stock), and E0 (commonly referred to as "neat" gasoline) contains no ethanol.

[3] There are other potential blend limit constraints affecting the RFS2 program, such as one limiting the percentage of biodiesel fuel that can be incorporated into blended diesel fuel. The ethanol blend wall, however, presents the greatest challenge to the workings of the program and is the primary subject addressed in this report. Unless otherwise noted, all references to "blend wall" in this report refer to the ethanol blend wall.

[4] E85 is an ethanol/gasoline fuel blend containing a relatively high percentage of ethanol by volume and a relatively low percentage of petroleum hydrocarbons by volume. While its name connotes a blend of 85% ethanol and 15% gasoline, the ethanol content of E85 is seasonally adjusted to meet ASTM recommended specifications and to improve vehicle cold-start and warm-up performance. Following the EIA's practice, we will analyze E85 sales under the assumption that fuel sold as E85 consists of 74% ethanol and 26% gasoline by volume on a year-round average basis.

[5] U.S. EPA, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis," EPA-420-R-10-006, Feb. 2010, ("EPA RFS2 RIA"), p.24.

[6] Wallace Tyner, "Big Time Issues Facing the Ethanol Industry," *Ethanol Today*, October 2009. Tyner expressed this same view at the American Coalition for Ethanol Conference in August 2010. ("We are at the blend wall. It is literally a wall. You cannot technically go beyond that wall." American Coalition for Ethanol, "Ethanol land use change drops under new Purdue modeling," August 11, 2010, http://ethanol.typepad.com/my_weblog/2010/08/ethanol-land-use-change-drops-under-new-purdue-modeling.html#tp)

2.2 Project Scope

The American Petroleum Institute ("API") has retained Charles River Associates ("CRA") to develop an independent assessment to determine the year when meeting the RFS2 standards will effectively require the ethanol content in motor gasoline to exceed 10 percent (i.e. in effect the ethanol blend wall constrains the amount of ethanol that can be blended in gasoline). In developing this analysis, CRA considered all the types of renewable fuels that were included in the RFS2 specifications as candidates to meet the standard, both singly and in various combinations. The analysis relied upon publicly available projections for gasoline and diesel fuel consumption provided by the Energy Information Administration [7] and other public information sources.

2.3 Results

The results of the CRA analysis indicate that the blend wall will likely become constraining in the 2011 – 2013 timeframe. In developing this conclusion, CRA based its analysis upon the Energy Information Administration's (EIA) Annual Energy Outlook 2011(AEO 2011) Reference Case. To assess the sensitivity of these results to higher future energy prices, CRA also analyzed the blend wall based upon the EIA AEO 2011 High Oil Price Case. The latter case was chosen because it had the closest agreement with the EIA Short Term Energy Outlook (June 2011). Both analyses reached essentially the same conclusion.

We also considered the feasibility of actions that would require new product introductions or dramatic changes in the use of what are today niche fuels; increasing E85 sales substantially beyond the levels currently projected in EIA's AEO2011 forecasts, introducing gasoline blends containing up to 15 percent ethanol by volume (E15) as a retail motor fuel, substituting E10 for neat gasoline (E0) in circumstances in which the latter fuel remains today's fuel of choice, or increasing the use of biodiesel fuel to levels well beyond those required to meet the RFS2 biomass-based diesel standard. We conclude that none of these actions could be implemented economically or quickly enough to prevent the ethanol blend wall from becoming constraining sometime in the years 2011 through 2013. The next paragraphs discuss these actions and their limitations in more detail.

2.3.1 Increasing sales of E85

Significantly expanding E85 sales would require at least two difficult transitions to occur in a relatively short time, one is customer demand for the fuel and the other is fuel availability. On the demand side, E85 itself must overcome consumer reluctance to purchase the fuel., Because E85 contains less energy per gallon than does gasoline, an FFV fueled with E85 has lower fuel economy and a more limited range than when the same vehicle is fueled with gasoline. This factor alone explains why many consumers have resisted using E85, and the problem has been only made worse during the frequent time periods when the consumer cost of E85 has exceeded that of gasoline on an energy-equivalent basis. Currently E85 accounts for less than 0.5 percent of the fuel used in FFVs.[8] As a result, many FFV owners have had

[7] Energy Information Administration, *Annual Energy Outlook 2011*, March, 2011. ("EIA AEO2011")

[8] CRA calculation based on EIA AEO2011 forecasts of E85 sales and total energy use by FFVs in 2011.

extensive experience using gasoline, but little or none using E85. One to two years is not sufficient time to introduce E85 to a large number of potentially new users and to convince them to use it. As economic theory suggests, cost-conscious consumers are unlikely to make widespread use of E85 unless it is priced at least no higher than E10 on an energy-equivalent basis, and there is no guarantee that this level of pricing will prevail. Moreover, even if such pricing could be achieved, still lower prices for E85 will almost surely be required to provide consumers with the necessary incentives to make the transition, as the EPA acknowledges.[9] Distributors of E85 would have to offer it at an additional discount on top of the discount needed to bring E85 to energy-content parity with E10 to overcome customer unfamiliarity with E85 and to compensate customers for the lower energy density of the fuel relative to gasoline, which requires E85 users to refuel their FFVs more frequently when they substitute E85 for gasoline.

On the supply side, making E85 more widely available would require fuel distributors and retail fuel station owners to make large investments in a considerable expansion of terminal and retail infrastructure in a very short period of time. As of the time of publishing this report, only about 2,400 U.S. fuel outlets (or approximately 1.5 percent of the number of U.S. retail fuel stations) had capacity to dispense E85. A rapid increase in the number of E85 stations seems unlikely, as it would require numerous fuel retailers, the vast majority of whom are small and independent business enterprises, to make large capital investments in the face of great uncertainty about consumer acceptance of the fuel.

2.3.2 Introducing E15 into the fuel supply

In October 2010 and again in January 2011, EPA granted partial, and conditional, waivers that, taken together, provide a necessary legal basis to allow E15 to be sold for use in model year 2001 and later light-duty motor vehicles.[10] In granting these waivers, however, EPA stated that it would not grant waivers permitting E15 use in model year 2000 and older light-duty motor vehicles or in any heavy-duty gasoline engines, motorcycles, off-road vehicles, or small engines. These limited waivers are only a first step in making E15 available to consumers. The commercial introduction of a new fuel or fuel additive involves a complex and time consuming process including changes to federal regulations and individual state regulations (regulations on what fuels can be sold vary from state to state), significant investments in infrastructure modifications, and the willingness of vehicle manufacturers to

[9] In the Regulatory Impact Analysis that accompanied the final RFS2 program rules, the EPA estimated that even by 2022, E85 would have to be discounted by approximately 19 cents per gallon relative to gasoline on an energy-equivalent basis if it is to be competitive with gasoline. On a volumetric basis, EPA calculates that E85 would have to be sold at roughly a 25 percent discount to gasoline in order for consumers to want to choose it regularly. EPA RFS2 RIA, pages 255-256.

[10] Environmental Protection Agency, “Partial Grant and Partial Denial of Clean Air Act Waiver Application Submitted by Growth Energy To Increase the Allowable Ethanol Content of Gasoline to 15 Percent; Decision of the Administrator,” October 13, 2010. (75 F.R. 6809, November 4, 2010) and “Partial Grant of Clean Air Act Waiver Application Submitted by Growth Energy To Increase the Allowable Ethanol Content of Gasoline to 15 Percent; Decision of the Administrator, January 21, 2011. (76 F.R. 4662, January 26, 2011).

modify vehicle warranty coverage. (Vehicle manufacturers have not designed or warrantied their vehicles other than FFVs to use E15 or any other fuel containing more than 10 percent ethanol.) A recent report from the United States Government Accountability Office identifies and discusses many of these barriers.[11] In a report issued in 2010, Sierra Research estimated that the process of removing these barriers could take years with a reasonable estimate being about five years.[12] Given the time required to gain necessary approvals, it appears nearly impossible that E15 can be commercially offered in large enough volumes by 2012-2013 in order to avoid reaching the blend wall.

2.3.3 Substituting E10 for E0

Neat gasoline (E0) accounts for a small but non-trivial fraction of all the gasoline sold today, but simply removing this product from sale and replacing all E0 with E10 is not a feasible action over the next several years. Two reasons help explain this conclusion and why not all gasoline sold today contains ethanol. First, in areas where both E10 and E0 are available, some consumers exhibit a preference for purchasing E0 rather than E10. Such preferences are particularly strong among consumers buying fuel to be used in applications such as marine outboard engines, older automobiles and motorcycles, and small off-road engines. Second, infrastructure and transportation constraints currently limit the availability of ethanol and ethanol-blended gasoline in some terminals and in some areas of the country. In many of these terminals and regions these constraints will likely continue to limit the amount of ethanol that can be blended into gasoline or render such blending entirely impractical.

2.3.4 Increasing sales of biodiesel

Just meeting the RFS2 program's proposed biomass-based diesel standards will require increasing biodiesel consumption to levels well beyond any seen before – and doing so in a period of only one to two years. Even if obligated parties should prove able to reach the biomass-based diesel standards that EPA recently proposed for 2013 , it is improbable that biodiesel consumption can increase over the next few years by the still greater amounts required to forestall the date when the E10 blend wall becomes constraining. The largest challenges are: (1) obtaining enough feedstock and; (2) quickly building a transportation/distribution infrastructure that is capable of handling volumes of biodiesel that are many times greater than those consumed in 2010 and prior years.

2.3.5 Additional compliance options: implications of economic theory

The RFS2 program establishes annual renewable volumes in four categories, and EPA implements the program by setting annual compliance standards based on the percentage of renewable fuels content sold in the compliance year. Changing the mix of fuels sold to favor those with average renewable content that exceeds the standard and decreasing sales of

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[11] United States Government Accountability Office, "BIOFUELS: Challenges to the Transportation, Sale, and Use of Intermediate Ethanol Blends, Report number GAO-11-513, June 2011. ("GAO Intermediate Ethanol Blends Report")

[12] Sierra Research, Inc., "Identification and Review of State/Federal Legislative and Regulatory Changes Required to the Introduction of New Transportation Fuels", Report No. SR2010-08-01, report prepared for American Petroleum Institute, August 4, 2010, ("Sierra Research Report"), page 2.

fuels with renewable content that falls short of the percentage standard is a viable short-run compliance option. In the earliest years of the program, during which the renewable fuels percentage standard is projected to be less than 10 percent of all transportation fuels, economic theory suggests that firms will want to produce more E10 than they otherwise might have and will have incentives to restrict their sales of neat gasoline and diesel fuels.

To accommodate volume shifts like these, E10 (and E15 and E85) prices would need to fall and prices for E0 and diesel fuels would need to rise relative to the prices that would have existed in the absence of the RFS2 program. This does not mean that transportation fuel prices would decline in general as a result of the RFS volume mandates. Overall, fuel prices could rise, leading to lower demand for transportation fuels. As the RFS2 program's annual renewable fuels volumes increase and annual renewable fuels percentage targets require more than 10 percent ethanol content averaged across all transportation fuels, firms will no longer have any incentive to increase sales of E10, and will instead need to limit their sales of this fuel as well. Prices for E10 and other mainstream fuels would all rise, choking overall transportation fuel supplies to match the available supply of Renewable Identification Numbers (RINs) that are the currency of RFS2 compliance. This may lead to a scenario in which steadily decreasing fuel sales would be incorporated into the EIA projections used by the EPA to set annual RFS2 targets. EPA would have to respond to these lower projected volumes by setting higher annual percentage targets, leading to further supply reductions, leading to still lower projected sales and still higher percentage targets, etc. Thus, the process of repeated cuts in production for domestic consumption, fuel cost increases, and lower sales volumes being incorporated into EIA forecast could create the conditions for a "death spiral" in which production and sales restrictions in one year create the conditions for far greater sales restrictions the next year. These restrictions would put intense upward pressure on consumer prices and would create excess capacity in the domestic fuel supply system.

2.4 Summary of Findings

Our independent assessment indicates that the ethanol blend wall will become constraining in one of the years between 2011 through 2013. In reaching this conclusion, we explored whether near-term actions to introduce new products or to effect dramatic changes in the sales volumes of certain existing niche fuels could alter this conclusion. We conclude that no such actions can be implemented economically or quickly enough to prevent the ethanol blend wall from becoming constraining in the 2011 through 2013 time period. Finally, we find that changing the mix of fuels sold to favor those with average renewable content that exceeds the average percentage standard in force in a year and decreasing sales of fuels with renewable content that falls short of the percentage standard represents a potentially viable short-run compliance option. Economic theory suggests that obligated parties will want to sell lower volumes of fuels with relatively low renewable content and higher volumes of fuels with relatively high renewable content than they would in the absence of the RFS2 program targets. The relative cost to consumers of various fuels will adjust to accommodate these changes in desired sales levels, and it is possible that the consumer cost of E10 fuel will initially fall even as the costs of other fuels, including diesel fuel, will rise. As RFS2 targets become increasingly more stringent, however, prices for E10 and other mainstream fuels should all rise, choking overall transportation fuel supplies to levels that will be determined by the availability of RINs generated by the sale of fuels with high renewable content, such as E85, that are today at best niche fuels and for which future demand is uncertain.

3 ASSESSMENT OF WHEN THE BLEND WALL WILL BECOME BINDING

In this section of the report we present and explain our core findings about the when the blend wall is likely to be reached. We first provide a description of the multi-step methodology we employed to determine when the blend wall is likely to be encountered, and then provide the results of our analysis. We then conclude by comparing our results with those previously published by the EPA, identifying key differences in assumptions that explain why we predict that the blend wall will likely be encountered at an earlier date than the EPA projected in its earlier analysis.

3.1 Methodology

We used a multi-step methodology, described below, to determine when the blend wall could become constraining.

1.) *Calculate Volumes of Ethanol in the Gasoline Pool*: Using the annual renewable fuels volume requirements set in the Energy Independence and Security Act of 2007 and as implemented by the EPA,[13] CRA calculated for each year the total volume of ethanol that would need to be included in the gasoline pool in order to comply with the mandate. CRA assumed that the cellulosic biofuel requirement would be met by producing cellulosic ethanol. CRA also assumed that the biomass based diesel requirement could be achieved in every year, but that the only additional biodiesel volumes that will be made available for sale are those already reflected in the EIA's AEO2011 forecast. The remaining volumes necessary to satisfy the advanced biofuel requirement would be met by sugar ethanol. We assumed that the difference between the total renewable fuel requirement and the advanced biofuel requirement would be met by corn ethanol. The sum of the ethanol produced to meet each of the mandate's requirements was assumed to be consumed as either E10 or E85 in the gasoline pool.

2.) *Calculate the total motor gasoline (including ethanol) demand in Btus*: Relying upon the EIA AEO2011 Table 46, we first determined the total demand for motor gasoline by year in Btus (because customers are concerned with travel or mileage, which is based on the energy content (Btus), not the volume, of transportation fuel), from EIA-forecasted demand for the sectors: light-duty vehicles, commercial trucks, freight trucks, buses, and recreational boats.

3.) *Calculate billions of gallons of ethanol and petroleum*: Consistent with the EIA methodology used in the EIA AEO, we divided demand for motor gasoline and ethanol

[13] Environmental Protection Agency, 40 CFR Part 80, Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule, 75 F.R. 14670, March 26, 2010, page 14674, Table I.A.1-1.

measured in Btus by the high heating values for petroleum and ethanol (measured in Btus per gallon) to compute the billions of gallons corresponding to the above Btu calculations.[14]

4.) *Calculate total diesel fuel demand in Btus and billions of gallons*: Using data from EIA's AEO2011, we summed diesel demand by sector, including light-duty trucks, commercial vehicles, freight vehicles, freight rail, domestic shipping, international shipping, military uses, and bus.

5.) *Calculate the annual demand in volume by year for E85*: We relied upon EIA's AEO2011 for forecasted annual E85 volumes.[15] Because of cold start and other vehicle operating concerns the actual ethanol content of fuel sold as E85 is typically less than 85 percent and varies on a seasonal basis. Using EIA's assumption that on an annual basis the average composition of E85 is 74 percent ethanol and 26 percent petroleum by volume, we calculated both ethanol and petroleum components of E85.[16]

6.) *Calculate volumes of neat gasoline (E0)*: The future share of neat gasoline in the total gasoline pool is uncertain. Neat gasoline exists today as a product because of the preferences of some consumers and because of infrastructure constraints that currently limit ethanol blending in some areas. As consumer preferences will be slow to change and as remaining infrastructure bottlenecks will take some time to resolve, at least some volumes of E0 will continue to be sold for at least the near future, although the exact amounts are uncertain.

To account for this uncertainty and the intense pressure now on the industry to maximize ethanol use, we calculated when the blend wall would be reached under two alternative assumptions. Our primary assumption, based on historical data, is that neat gasoline will retain a 10 percent share of all gasoline sold.[17] As a sensitivity analysis, we also analyzed the effect on the blend wall if the share of E0 declines to 5 percent. While recent historical experience provides no evidence that E0's share can be reduced to this level over the next one to three years, we decided to use this lower share as a test of the robustness of our findings against a scenario in which fuel providers can react to higher RIN prices quickly and are able to execute aggressive actions to eliminate any infrastructure barriers now standing in the way of near-universal E10 availability.

[14] These computed volumes will differ from those projected by EIA, because the volume of ethanol we calculated in step 1 as necessary to meet the RFS2 targets will differ from the ethanol volumes projected in the AEO. The ethanol and petroleum-based gasoline volumes we calculate will, by design, provide exactly the same energy content as the volumes originally projected by EIA.

[15] EIA AEO2011 Reference Case table 11, row 1617.

[16] This assumption may overstate the amount of ethanol that will be consumed in the form of E85. ASTM has recently established a fuel specification allowing as low as 51% ethanol to be used for refueling FFVs. Also, increased use of blender pumps may further reduce the delivered ethanol concentration for FFVs below the 74% assumption.

[17] Tyner and Viteri estimate that 10 percent of all gasoline is neat. (Wallace Tyner and Daniela Viteri, "Implications of blending limits on the US ethanol and biofuels market," *Biofuels* 1(2) 2010, pages 251-253). Reviewing the EIA's weekly refiner and blender net production data, we find that the share of neat gasoline has dipped to slightly under 11 percent in the fall of 2010 and has averaged about 12 percent for the past three months.

7.) *Compute the year in which blend wall becomes constraining under EIA's assumptions*: For each future year, we calculated the percentage of ethanol that the RFS2 regulations will require to be blended into all motor gasoline into which ethanol can be blended. This percentage is calculated as the ratio of the gallons of ethanol required to meet the RFS2 mandate less any ethanol consumed in the form of E85 divided by the total gallons of gasoline into which ethanol can be blended (i.e., E85 and E0 are excluded). If this ratio exceeds ten percent, the blend wall is assumed to be binding. The required gallons of ethanol in E10 equals the RFS2 mandated amount of ethanol less the gallons of ethanol in E85 predicted by the EIA. The amount of motor gasoline into which ethanol can be blended equals the total demand for motor gasoline (non-diesel transportation fuels) less gallons of neat gasoline and E85.

8.) Using the EIA assumptions for E85 consumption and biodiesel sales that do not exceed the RFS2 biomass-based diesel requirements, and ignoring any RIN carryover from 2010, the blend wall becomes binding by 2011 or 2012 (see Table 1 in Section 3.2 that follows). EIA forecasts that E85 sales will increase from 33 million gallons to 58 million gallons in 2012. *If E85 sales increased by an additional 20 million gallons, to 78 million gallons,[18] or the share of neat gasoline declined (e.g., a decline from 10 percent to 9.5 percent) then the first year the blend wall is exceeded is 2012*.

The blend wall problem could be postponed by consumption increases for E85, biodiesel, or both. The investments and other changes necessary to allow sufficient additional quantities of fuels to be produced, distributed and sold must occur over a very short time period; i.e. in the next one to two years. We have analyzed the practicality of increasing the quantities of E85 and biodiesel to be consumed in order to delay exceeding the ethanol blend wall.

9.) *Assess the practicality of building enough E85 retail stations quickly enough to delay reaching the blend wall*: Minnesota currently has the most extensively developed E85 refueling infrastructure. Based upon an analysis of data collected in Minnesota, David Greene and his colleagues[19] estimated that in order to avoid paying an availability penalty,[20] 10 percent to 20 percent of all fuel stations must offer E85.[21] As of the time of publishing this report, outlets dispensing E85 represented about 1.5 percent of all U.S. service stations (~2,400/160,000). In recent years, the rate of net addition to the population of U.S. fuel stations offering E85 has ranged between approximately 200 and 500 additional stations per year. Assuming an annual growth rate of 25 percent for new E85 stations based off of the upper end of this range (i.e., 625 additional locations that dispense E85), an upper bound

[18] This would mean that total E85 sales in 2012 would need to increase by about 2.4 times relative to forecasted sales for 2011. There is also a history of revising downward E85 sales. The EIA AEO2010 reported E85 sales in 2008 of 65 million gallons. In the EIA AEO2011, this was revised downward to 13 million gallons.

[19], David Greene, Jason Zhou, and W. T. Wilson, "Consumer Choice of E85: Lessons from Minnesota's Experience," Submitted 8/1/08, Transportation Research Board 09-3018.

[20] Availability penalty is the financial incentive that retail station operators would have to offer consumers to persuade them to drive to stations that are not conveniently located. It does not include any financial incentives needed to persuade consumers to purchase E85 even if it is available at the pump.

[21] Greene, Zhou, and Wilson, "Consumer Choice of E85: Lessons from Minnesota's Experience".

range of perhaps an additional 1500-2500 fueling stations could be converted by 2013, resulting in a total of as many as 4,300 fueling stations capable of providing E85. This would represent about 3 percent of fueling stations; far below the market share necessary to support widespread E85 usage. This report discusses the issues constraining near-term growth in E85 sales in greater detail in Section 3.1.1.

10.) *Assess the biodiesel production potential:* We assume that no additional biodiesel volumes will be forthcoming beyond the volumes needed to satisfy the RFS2 biomass-derived diesel targets that EPA has recently proposed for years 2012 and 2013, one billion gallons in 2012 and 1.28 billion gallons in 2013 and (by assumption) in subsequent years.[22] While in theory, there may be enough available domestic nameplate biodiesel capacity to produce perhaps twice these volumes of fatty acid methyl ester ("FAME") biodiesel fuel, even the one billion gallon level is almost 50 percent more than the peak level of domestic biodiesel production prior to RFS2 (678 million gallons in 2008) and nearly three times higher than the pre-RFS2 peak in domestic biodiesel consumption (358 billion gallons in 2007).

Achieving even the one billion gallon (or higher) per year levels of biodiesel use mandated by the RFS2 rules is thus without historic precedent and will require new investments in the infrastructure needed to transport, store, blend, and sell these higher volumes of FAME-based biodiesel fuels. This infrastructure will be costly and take time to install. Furthermore, there are certain limitations created by the properties of FAME-based biodiesel, particularly in the northern regions of the United States, (e.g., the need to provide and maintain heated or insulated transportation equipment and storage tank capacity to prevent the fuels from clouding or congealing during winter months to facilitate blending).[23] Finally, efforts to increase biodiesel production on a larger scale may lead to problems in obtaining the necessary feedstocks, as even meeting the one billion gallon per year RFS2 biomass-derived diesel fuel target will require the processing of oils and fats that are equivalent to roughly 20 percent of the current U.S. soybean crop. Section 4.1.4 of this report presents a fuller discussion of the factors likely to limit biodiesel production and sales volumes over the next one to two years.

11.) Determine whether additional E85 or biodiesel consumption can postpone when the E10 blend wall becomes constraining. For each year, we calculated the ethanol content in E10 in order to comply with the RFS2 mandate, including projections for E85 and biomass-based diesel to lessen the burden. The blend wall binds between 2011 and 2013, using

[22] EPA proposed these volume targets in a proposed rulemaking issued on June 21, 2011 that also sets forth EPA's proposed percentage targets for all of the RFS standards for 2012. 75 F.R. 38444, July 1, 2011. We base the assumption that no additional biodiesel will be sold beyond the volumes required to meet these proposed targets primarily on our assessment that biodiesel fuel will remain uncompetitive with petroleum-derived diesel fuel on an energy equivalent basis and will continue to be a more expensive than ethanol as a means to increase the average renewable content of transportation fuels.

[23] Although some of these handling problems could be addressed by hydrotreating vegetable oils or animal fats to create a pure hydrocarbon fuel that RFS2 regulations refer to as" renewable biodiesel", the increased cost, refining, biomass infrastructure, energy consumption, air emissions, permitting, and regulatory constraints (including the prohibition of refinery co-processing with petroleum) associated with this process make widespread adoption of this fuel unlikely in the near term.

either of the two assumptions about the share of neat gasoline (10 percent and 5 percent), (see Table 2 below).

3.2 Findings

Tables 1 and 2 summarize the share of ethanol needed in non-E85 motor gasoline to comply with RFS2. The entries highlighted in red indicate when the blend wall is constraining. Under the EIA assumptions about likely E85 consumption, the blend wall is constraining in 2011 or 2012, depending on the share of the neat gasoline in the gasoline pool. Even in a "max E85" scenario that relies upon extremely optimistic and aggressive assumptions about growth in E85 availability and consumer acceptance,[24] the blend wall still becomes constraining in either 2011 or 2012 depending on the neat gasoline share. With relatively small changes in projected fuel consumption or actual renewable fuels volumes these dates might slip, at most, one year, to 2012 or 2013, respectively.

Table 1: Percentage of ethanol in non-E85 motor gasoline under the EIA AEO2011 assumptions and alternate assumptions about the share of neat gasoline (E0)

	EIA Assumptions	
	5% Neat	10% Neat
2011	9.6%	10.2%
2012	10.3%	10.8%
2013	11.0%	11.6%
2014	12.0%	12.7%

Table 2: Percentage of ethanol in non-E85 motor gasoline under "Max E85" assumptions about the penetration of E85 and alternate assumptions about the share of neat gasoline (E0)

	Optimistic E85	
	5% Neat	10% Neat
2011	9.5%	10.0%
2012	10.0%	10.6%
2013	10.6%	11.2%
2014	11.3%	11.9%

24 This scenario rests on the station construction estimates discussed in step 9 of the section 2.2 (rapid and geographically concentrated growth in the number of E85 stations) and an assumption of 100% refueling of FFVs with E85 in any area in which 20 percent or more of fueling stations offer E85 for sale.

3.3 Reconciling our findings with those of the EPA

In the Regulatory Impact Analysis (RIA) prepared in connection with the final rule establishing the RFS2 program, EPA provided its own estimates of when the blend wall will become binding.[25] EPA estimated that the blend wall would be reached as early as 2013 or as late as 2015,[26] with the precise year depending on the success of biomass-to-liquids (BTL) fuels technology in displacing some of the ethanol that would otherwise be needed to satisfy the RFS2 renewable fuels standard. Our findings presented above differ from EPA's in that we find that the blend wall should become binding as early as in 2011 or, at the latest, by 2013.

What explains these different conclusions? Although the RIA does not provide a detailed description of the methodology EPA used to derive its estimates of when the blend wall will become binding, we have found that differences in the choices made concerning three critical assumptions suffice to explain the differences between EPA's estimates of when the blend wall might be reached and our own. Utilizing exactly the same methodology as described in Section 2.3 above, we have been able to reproduce the findings presented in the RIA simply by replacing our assumptions in each of these three areas with those chosen by EPA. For this reason, we do not need to speculate about how the EPA's methodology might differ from our own, as it appears that given the same inputs, the two approaches produce broadly the same results.

Three critical areas, noted below, suffice to explain the differences between the EPA estimates and our own:

1. Estimates of gasoline and diesel fuel demand in transportation uses for the years 2011 through 2015;
2. Assumptions about the role, if any, that biomass-to-liquid technologies will play in meeting the RFS2 target; and
3. Assumptions about the future supply of and demand for neat gasoline (E0).

In the first of these areas, EPA's calculations involving energy and ethanol consumption were based upon fuel consumption estimates derived from the EIA's Annual Energy Outlook 2009[27], while we have relied on the consumption estimates contained in EIA's more recent AEO2011. The AEO2011 reference case estimates of transportation fuel energy consumption are lower than those found in AEO2009 for each year between 2011 and 2014.[28] The EPA's use of the higher consumption estimates allows the RFS2 renewable fuels target volumes to be spread over higher fuel volumes in each of these years, resulting in lower estimates of the EPA's annual RFS2 renewable fuels target as expressed in percentage terms. These lower estimated percentage obligations work to defer the date on

[25] EPA RFS2 RIA, pages 238- 241.

[26] Ibid., page 241.

[27] Ibid., page 238.

[28] AEO2011 estimates are 5.3 percent lower for 2011 than the same estimates found in AEO2009, with the discrepancy lessening over time (AEO2011 reference case energy consumption projections are lower than those reported in AEO2009 by 4.2 percent for 2012, 2.4, percent for 2013 and 1.3 percent for 2014).

which the percentage target becomes large enough to cause the blend wall to become binding.

In the second of these areas, EPA has chosen to analyze three scenarios that differ in their assumptions about the contribution that ethanol will play in meeting the RFS renewable fuel targets. These are, referred to as the “low-ethanol”, “high-ethanol” and “mid-ethanol” control cases, with the mid-ethanol case serving as EPA’s primary case. In the low-ethanol case, the EPA assumes that biomass-to-liquid (BTL) fuels will quickly account for a significant and growing fraction of the fuels available to satisfy the RFS2 renewable fuels target, reducing the volume of ethanol that would otherwise be needed to satisfy the target. In this scenario, the EPA finds that the blend wall will not be reached until 2015. In the mid-ethanol case, the EPA assumes that BTL fuel use will grow, but at a more modest pace than assumed in the low-ethanol case, As a result the blend wall will be encountered in 2014, one year earlier than in the low-ethanol case. Finally, in its high-ethanol case the EPA assumes that BTL fuels will make no contribution to meeting the renewable fuels target at any point throughout its forecast period, requiring the use of higher volumes of ethanol. As a consequence, the EPA estimates the blend wall will first become binding in 2013 in this scenario.

The assumption in our analysis is that BTL liquid fuels will not be used in any appreciable quantities in our forecast horizon. As such, our analysis is most closely comparable to EPA’s “high-ethanol” case, and our results overlap those of the EPA; the EPA predicting the blend wall will be reached in 2013, while we are predicting that it may be reached in 2011 or 2012, but certainly no later than 2013.

Finally, the EPA analysis does not appear to place any constraints on the ability of E10 to displace E0 consumption fully in the near term, while we assume that E0 will continue to account for some fraction (10 percent or 5 percent) of total gasoline sales, at least for the immediate future. Assuming that E0 will soon cease to exist as a motor fuel allows EPA to spread its assumed ethanol volumes over a larger fraction of the gasoline pool, effectively deferring the date when the blend wall is estimated to become binding.

We believe that our assumptions in each of these three areas are more reasonable than those adopted in the EPA’s analyses. First, we have been able to conduct our analysis on the basis of a more up-to-date, and presumably more accurate, EIA AEO forecast than was available to EPA at the time it conducted its analysis. Second, we are aware of no current plans to produce BTL fuels in any significant quantities over the next several years; as such we believe that the assumption used in EPA’s’ “high-ethanol” control case is the correct one and that apart from biodiesel volumes sufficient to meet the RFS2 biomass-based diesel target, virtually all of the fuel needed to meet the renewable fuels standard will consist of ethanol, at least for the next several years. Finally, for reasons we discuss in greater detail in Section 4.1.3 of this report, we believe that it is unrealistic to expect E0 to quickly disappear as a transportation fuel, as both consumer demand for the fuel and infrastructure limitations make it unlikely that E0 will disappear in the near future.

3.4 Conclusion

Our analysis demonstrates that the blend wall is almost certain to become constraining in the 2011-2013 timeframe. The results are sensitive to two key parameters: the fraction of the gasoline pool that is accounted for by consumption of neat gasoline and the frequency with which the projected stock of FFVs are refueled with E85. More optimistic assumptions about the near-term growth potential for E85 and biodiesel usage would not materially impact our conclusion.

4 CHARACTERIZATION OF THE ECONOMICS AND COMPLIANCE ISSUES OF MOTOR FUEL PRODUCTION UNDER RSF2 WITH THE BLEND WALL CONSTRAINT BINDING

4.1 Major changes in fuel demand and supply conditions cannot be relied upon to forestall reaching the blend wall

In the preceding section of this report, we presented our analyses of when the E10 blend wall would likely become binding and estimated that even with increased E85 sales, the E10 blend wall will be reached in the 2011 to 2013 time period.

In this section of the report, we provide in more detail the basis for our estimate of the maximum practicable level of E85 sales. We also consider whether other changes to the consumption levels for “niche” fuels other than E85 could, in practice, be used to make up the gap that would remain between available RINs and the E10 blend wall, even after realistic opportunities to sell more E85 have been fully exploited.[29]

We consider three such possibilities: introducing E15 as a commercially distributed fuel; eliminating or sharply reducing sales of neat gasoline (E0); and incorporating into the diesel fuel pool more biodiesel blendstock (B100) than would be needed either 1) to meet the RFS2 program’s biomass-based diesel fuel requirement or 2) to match the annual biodiesel consumption forecasts found in EIAs AEO2011, whichever is greater. We conclude that none of these actions are likely to be achievable to the extent and within the short time period required to prevent reaching the E10 blend wall in the near future, as numerous fundamental, economic and logistical barriers, to be explained below, stand in the way.

4.1.1 E85

One way that fuel suppliers could comply with RFS2 would be to increase their production and sales of E85 significantly above today’s level. However, there is no guarantee that consumers presented with a choice to purchase either E85 or E10 would choose E85. Furthermore, expanding E85 sales to the levels that would be required to avoid hitting the blend wall would require a very rapid near-term expansion of retail infrastructure at rates that exceed historical levels.

[29] Our analysis ignores the possibility of using “excess” RINs created in prior years as one (partial) means of achieving RFS compliance. Our analysis thus assumes that achieving compliance across all obligated parties will require matching aggregate RIN obligations to aggregate RIN generation on a year-by-year basis. Our choice to adopt this assumption should not affect the results of our analysis in any material fashion, given the contrast between the very large numbers of RINs that will be required to satisfy future RFS2 obligations in aggregate and the relatively small existing stock of surplus RINs. This existing stock can support, at best, only a limited buffer between the total number of RINs generated in future compliance year and the total RIN obligations incurred in those years.

Will Consumers Purchase E85?

Even if it were possible to offer E85 at every retail station or, at a minimum, selectively locate stations offering E85 in areas with a large density of FFVs, there would be no guarantee that consumers would purchase E85 in sufficient quantities to avoid reaching the blend wall over the next couple of years. As an initial matter, as economic theory suggests and the EPA acknowledges, E85 would have to be priced at a discount to gasoline to induce cost-conscious FFV owners to buy E85 instead of gasoline. E85 has lower energy content per gallon than E10, so, at a minimum, E85 would have to be priced no higher than gasoline on an energy-equivalent basis if it is to attract any widespread consumer interest. But energy-equivalent pricing is not likely to suffice to attract many consumers to E85; instead E85 will need to be priced at a further discount to E10 to offset an additional E85 disadvantage. E85's lower energy density means that FFV owners will experience a reduced driving range when they opt to use E85 rather than E10; as a result, FFV owners using E85 will need to refuel more often than those using E10. E85 pricing discounts will be required to compensate customers for these inconveniences.[30] Current fuel procurement costs are higher for E85 than for E10. The current price relationship between E85 and gasoline favors gasoline when one accounts for the range penalty.[31]

In addition, E85 must overcome most consumers' unfamiliarity with the fuel. EIA AEO2011 data suggest that less than 0.5 percent of FFV refuelings in 2011 will be made with E85. Many FFV owners thus have had no experience with E85, but have had extensive experience with gasoline. It is unclear whether one to two years is sufficient time to introduce the E85 product to new potential users and convince them to use it on a regular basis. As with the introduction of any new product that is a close substitute for a well-established incumbent, the distributors of the new product would need to offer it at an even greater discount than would be warranted just for compensating for E85's energy density and refueling disadvantages, if they wanted to build market share. Under these circumstances, it is not at all clear that the appropriate relative market prices would be established to clear markets.

Barriers Limiting the Availability of E85 to Consumers

In addition to overcoming consumer resistance, a successful effort to increase the use of E85 will have to overcome numerous barriers that currently limit the fuel's availability in the marketplace. These include the lack of sufficient infrastructure at several points in the fuel production and distribution chain, most notably at the retail level. Progress in overcoming these barriers is likely to be slowed by the relatively high investment costs and uncertain returns facing the parties that will be required to install the necessary infrastructure, particularly in the case of the numerous small and independent business people that own individual retail fuel stations.

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30 The exact extent of the pricing discounts required to compensate consumers for these inconveniences is uncertain, EPA estimates the discount needed to compensate consumers for additional time spent refueling with E85 rather than gasoline at roughly 5 cents per gallon. In addition, EPA estimates that even by 2022 an additional availability penalty of roughly 14 cents per gallon will be needed to compensate FFV owners for the relatively limited geographical availability of E85. EPA RFS2 RIA, pages 255-256.

31 EIA AEO2011 forecasts for E85 and motor gasoline show this price relationship.

Transportation and Distribution of the Volumes of Ethanol Needed to Meet RFS2 Targets

Providing sufficient quantities of ethanol to be blended into E85 (or other fuels) in order to meet the volume requirements needed to comply with the RFS2 standards will require investments in ethanol infrastructure. These investments in the ethanol infrastructure are generic to all measures that involve incorporating greater ethanol volumes into the gasoline fuel pool; they are no different for E85 than they are for producing and distributing the same additional volumes of ethanol to be incorporated into other gasoline blends. For this reason, a recently issued GAO report on barriers to the use of E15 is equally relevant to similar issues surrounding the greater use of E85. The GAO report concludes that existing transportation infrastructure should be adequate to move the amounts of ethanol that will be required to meet the RFS2 standards through the year 2015. Thereafter expansion of transportation capacity will be required. But it also concludes that considerable investments in retail infrastructure will be required in the very near future, if E15 is to reach customers. Much the same is true for E85. However, retail fuel station owners understand that consumers may choose not to purchase E85. The uncertainty concerning the acceptance of E85 by consumers combined with physical constraints, and retailers' lack of financial incentives to make these types of investments means that it is highly unlikely that many retailers will make these investments in the near future. These points are addressed in greater detail below.

Economic Incentives for Retail Station Owners

An important consideration in policy construction is the impact of policy incentives upon the stakeholders. Under the renewable fuels standard the burden of compliance is placed upon the fuel producer (i.e., refiners). Retail fuel station operators do not have a compliance burden, as EPA acknowledges. [32] As a result, there is a disconnect between incentives and actions, and successful implementation of the RFS2 program will require some way to induce retail station owners to make investments in the infrastructure improvements and additional equipment that would allow them to sell E85 (or E15), even though they are not obliged to do so.

According to the GAO report, only about one percent of retail outlets are owned and operated by major oil companies, about fifty-two percent are operated by independent business owners who sell fuel under a major oil company brand name, and the remaining retail outlets are owned by independent business owners who provide unbranded gasoline. [33]

About seventy percent of retail outlets are convenience stores and fifty six percent of the convenience stores are single outlet owners. Convenience stores make most of their profit

[32] In comments on a draft of the recent GAO E15 study, EPA Assistant Administrator Mathy Stanislaus notes that "It is not … mandatory for a tank owner to move to the intermediate blends of ethanol (such as E15)." GAO Intermediate Ethanol Blends Report, Appendix III, page 48.

[33] GAO Report, page 8.

selling merchandise such as food and beverages.[34] Their profit on gasoline was about nine cents per gallon in 2010.[35]

In general, retail outlets are currently not configured to provide an additional product like E85 or E15. A typical retail outlet is configured to have two underground storage tanks that provide three grades of gasoline. [36] In order to offer E85 or E15 as well as E10, retail outlets will need to make equipment investments in storage tanks and other equipment, provided that they have space to allow extra tankage.[37] Retail outlets are not obligated to provide E85 or E15, so their investment decisions will be based upon weighing the profit potential from E15 or E85 versus the financial risk. Retail owners may be reluctant to make this investment when it is not clear that consumers will prefer E85 or E15 to E10 or that future product prices would provide consumers with any incentive to switch fuels. Furthermore, each retail outlet owner would take into consideration the size of the potential market.

Even though there are approximately 11 million FFVs on the road today according to EIA estimates, this vehicle population constitutes less than 5 percent of the light duty vehicle fleet. [38] A retailer is in effect being asked to make a large investment in order to serve a relatively small, niche FFV market, under an assumption that pricing and consumer acceptance issues would be satisfactorily resolved such that FFV owners will ultimately come to prefer E85 to E10. This would require a leap of faith for many such owners, as the experience with E85 to date has revealed no such strongly held consumer preferences. In fact, most of today's FFV owners have never fueled their vehicles with E85. The use of E85 in FFVs is expected to remain at very low levels in the near term; taken together, the EIA's 2011 AEO forecasts of E85 sales and total energy use by FFVs, imply that E85 will account for only about 0.5% of all of the energy used in FFVs in 2011.

The burden of investment required to be able to sell a new fuel when future demand for that fuel is highly uncertain is likely to be especially concerning to single outlet owners. For them, an investment of the scale that will be required is substantial and represents a uniquely large financial risk because of their small scale. As a result, many retail owners may postpone investment in order to assess whether or not consumers prefer E85 to E10.

Despite these very real issues, we analyzed a highly optimistic scenario in which these problems can somehow be overcome, some retail operators would find the means to invest in E85 infrastructure, and E85 would become cost-competitive with E10. Our analysis finds that even if E85 stations are created at rates that are extremely high by historical standards, the

[34] GAO Intermediate Ethanol Blends Report, page 27.

[35] Ibid.

[36] One storage tank contains regular gasoline and the other premium. The two grades are mixed to provide mid-grade gasoline.

[37] EIA assumes that the cost to retrofit a retail station is $45,000. U.S. Energy Information Administration, Assumptions to the Annual Energy Outlook 2011, page 147. The GAO Intermediate Ethanol Blends Report estimates the cost to be $100,000.

[38] Calculated from data found in AEO2011, Table 58, "Light-Duty Vehicle Stock by Technology Type, Reference Case". Even by 2013, the AE0 20011 forecast suggests that FFVs will constitute less than 8 percent of the light duty vehicle fleet.

resulting E85 (and FFV) infrastructure would be insufficient to sell the high volumes of E85 that would be required to postpone reaching the blend wall beyond 2013. The basis for this conclusion is presented below.

The Minnesota Experience

An issue not well understood is how the demand for E85 is affected by the availability of retail stations offering E85 for sale. There are two components to this issue: First the ease with which a consumer in a given location can find a retail station offering E85 (i.e. the market share of E85 stations) and second, the willingness of consumers to purchase E85.

The state of Minnesota has the largest number (approximately 350) and highest number of E85 stations per capita of any state in the country.[39] As a result, much of the limited research on potential for E85 demand has been based upon data gathered in Minnesota. In a paper first circulated in 2008, researchers affiliated with the National Renewable Energy Laboratory found that E85 accounted for roughly 19% of the average fuel use by Minnesota's FFV drivers during a year (2006) when 10 percent to 13 percent of stations in the state were offering E85.[40]

In an unpublished paper presented at the 2008 meetings of the Transportation Research Board, David Greene and his coauthors rely on Minnesota data to estimate the relationship between E85 availability and E85 use among FFV owners. They conclude "that E85 availability at 10 percent to 20 percent of retail outlets might be sufficient to achieve a very substantial market share given an appropriate price advantage for E85." Greene, Zhou, and Wilson estimate that there would be no availability penalty[41] (i.e. no cost penalty for limited availability of E85 retail stations), if E85 were available in at least 20 percent of retail outlets.[42] In other words, this study suggests that only at a 20 percent (or higher) market share of E85 retail stations does the availability penalty disappear. At lower market shares, consumers would need an incentive just to drive to an E85 retail station. This is in addition to any incentive that would have to be given to consumers to overcome customer reluctance to purchase E85 once there.

Could E85 Stations be Built Quickly Enough to Avoid Reaching the Blend Wall?

Our analysis in Section 2 showed that the blend wall will likely be reached in the 2011-2013 timeframe. We wanted to test the hypothesis that it was unrealistic to assume that enough E85 stations could be built in the next two years to allow E85 to be offered to the public at a

[39] United States Department of Energy, Alternative Fuels Data Center, "Alternative Fuel Stations by State and Fuel Type", (http://www.afdc.energy.gov/afdc/data/docs/alt_fueling_stations_fuel.xls) and CRA calculations

[40] P. Bromiley, T. Gerlach, K. Marczak, M. Taylor, and L. Dobrovolny, "Statistical Analysis of the Factors Influencing Consumer Use of E85," (NREL/SR-540-42984), July 2008. During 2006, the average price of E85 across all stations in Minnesota was about 9 percent higher than the average price of gasoline on a per-Btu basis. There was, however, considerable variation in E85 prices across stations, with the lowest monthly E85 price averaging almost 13 percent less than the price of gasoline on a per-Btu basis. CRA calculations based on Bromiley et al, Table 1, page 6.

[41] The availability penalty is the incentive that fuel suppliers would have to offer consumer to persuade them to find and drive extra distance to an E85 retail station that is not convenient to them.

[42] See figure 4 in Greene, Zhou, and Wilson, "Consumer Choice: Lessons of Minnesota's E85 Experience.

sufficient number of locations to delay reaching the blend wall. In order to perform this test, we assumed that there were no other issues related to dispensing E85 and consumer acceptance. We know that in reality there are a host of other issues related to the distribution, sale, and consumer acceptance of E85. However, if it were not realistic to expect that enough E85 retail stations could be built under this set of assumptions, then it would be even less likely to expect that the stations could be built given the other institutional and consumer impediments that E85 faces.

Under the assumption that biodiesel fuel consumption achieve the levels that EIA forecasts in the AEO2011 reference case, the amount of E85 that must be sold to comply with the RFS2 levels and avoid reaching the blend wall in 2012 and 2013 corresponds to 15 percent and 24 percent of the FFV fleet refueling solely with E85. These percentages are computed by dividing the number of gallons of E85 that must be consumed to comply with RFS2 by the product of the EIA's forecast for the stock of FFVs and the average fuel consumption of these vehicles.

We assumed that fuel marketers could concentrate the new E85 stations in locations that were easily accessible by the necessary percentage of the FFV fleet, and that all FFV owners in those locations would use E85 exclusively. That is, fuel marketers could retrofit enough retail outlets so that 20 percent of stations sell E85 in locations that are easily accessible by 15 percent of FFVs in 2012 and 24 percent of FFVs in 2013.

Therefore, 20%*15% and 20%*24% of the stations in 2012 and 2013, respectively, would need E85 pumps. These formulas imply roughly 4,700 and 7,600 E85 outlets would be needed in 2012 and 2013, respectively.

As of May, 2011, there were about 2,400 stations with E85 pumps,[43] although not all of these are currently open to the general public. Some are for exclusive use by fleets. Making the optimistic assumption that the existing 2,400 stations are strategically located in the same locations where all the new E85 stations would be added, fuel marketers would need to retrofit or construct almost 2,000 stations during the next year and almost 6,000 stations over the next 2 years (or on average 3,000 stations per year).

[43] http://www.afdc.energy.gov/afdc/fuels/stations_counts.htm.

Table 3: Number of E85 stations in the United States, 2005-2010

	# of E85 Stations	
	Total	Annual Change
2005	436	
2006	762	326
2007	1,208	446
2008	1,644	436
2009	1,928	284
2010	2,142	214

Source: United States Department of Energy, Alternative Fuels Data Center, http://www.afdc.energy.gov/afdc/data/docs/alt_fueling_stations_fuel.xls

The historical rate of adding stations with E85 pumps ranges from about 300-500 stations/year (see Table 1). To meet the 2013 requirement would require a more than doubling of the historical retrofit rate. By 2014, the number of additional E85 retail stations would be about five times greater than what has occurred over the last five years. This level of construction is highly unlikely, particularly given the highly uncertain business case for station owners contemplating the necessary investments.

4.1.2 E15: Host of changes required despite EPA waivers for vehicles built since MY2000

Another potential approach to avoid reaching the blend wall is to increase the upper limit of ethanol content in conventional gasoline from 10 percent by volume (E10) to as much as 15 percent by volume (E15). As is the case with expanded sales of E85, introducing E15 to the market in significant volumes would require rapid changes in transportation, distribution and retail infrastructure to accommodate a new fuel and the higher volumes of ethanol that its production would require. Unlike expanding E85 sales to FFV owners, introducing E15 faces significant legal and regulatory hurdles as well as the prospect of marketing a fuel in the face of automaker opposition.

Last year, EPA granted a partial waiver to allow gasoline that contains greater than 10 volume percent ethanol and up to 15 volume percent ethanol (E15) for use in model year 2007 and newer light-duty motor vehicles.[44] In granting the waiver, EPA further stated that it would not grant a waiver for model year 2000 and older light-duty motor vehicles, as well as all heavy-duty gasoline engines and several other classes of gasoline-consuming equipment. In January EPA granted a second partial waiver allowing E15 to be sold for use in model year 2001 through 2007 light-duty motor vehicles.[45]

[44] 75 F.R. 6809, November 4, 2010.

[45] 76 F.R. 4662, January 26, 2001.

The commercial introduction of a new fuel or fuel additive involves a complex and time consuming process of regulatory approvals, infrastructure modifications, and warranty changes. These involve time-consuming changes and approvals under federal regulations, individual state regulations (regulations on what fuels can be sold vary from state to state), significant investments in infrastructure modifications, and the willingness of vehicle manufacturers to modify vehicle warranty coverage. In a recent report, Sierra Research estimates that this process could take years with a reasonable estimate being about five years.[46] Given the time required to gain necessary approvals, it does not appear sensible to assume that E10+ can be commercially offered in large enough volumes by 2012-2013 in order to delay reaching the blend wall. We identify and discuss below some key regulatory and other barriers that will effectively prevent E15 sales from providing any near-term relief from the E10 blend wall.

Federal regulations

Before a new fuel or fuel additive can be offered for commercial sale it must comply with a number of federal fuel and environmental regulations.

1.) Under the Clean Air Act, E15 or any other gasoline/ethanol blend containing more than 10 percent, but no more than 15 percent ethanol by volume are not considered "substantially similar" to existing fuels and as such must undergo testing before EPA will consider granting a waiver. EPA granted partial waivers for E15 in October 2010 and again in January 2011. It is not clear if or when EPA will decide whether to permit commercial sale of E15 to a broader market; indeed, as noted above, EPA has, at least for now, ruled out granting a waiver for the use of E15 in model year 2000 and earlier vehicles.

2.) All fuels and fuel additives must be registered with the EPA. This involves filing basic registration information and satisfactorily completing a literature search and testing to determine the emissions and health effects resulting from use of the fuel. Sierra Research reports that the testing is extensive and can take years to complete. As Margo T. Oge, Director of EPA's Office of Transportation and Air Quality, noted in recent Congressional testimony, "[s]ince EPA has yet to receive or act on a complete E15 registration application, E15 may not be lawfully sold."[47]

3.) E10 will still be needed for pre-2001 vehicles and other gasoline-consuming equipment – so retailers would have to sell two different low-ethanol blends, E10 and an E15 fuel, which is likely to lead to instances in which E15 is improperly introduced into the fuel systems of pre-2001 vehicles. EPA issued a final rule, effective August 24, 2011,[48] that

[46] Sierra Research Report, page 2.

[47] "As a new gasoline, E15 must be registered under the Clean Air Act before it may be introduced into commerce. Since EPA has yet to receive or act on a complete E15 registration application, E15 may not yet be lawfully sold." Margo T Oge, Director, Office of Transportation and Air Quality, Office of Air and Radiation, U.S. Environmental Protection Agency, written statement before the Subcommittee on Energy and Environment, Committee on Science, Space, and Technology, U.S. House of Representatives, July 7, 2011.

[48] Environmental Protection Agency, Regulation To Mitigate the Misfueling of Vehicles and Engines With Gasoline Containing Greater Than Ten Volume Percent Ethanol and Modifications to the Reformulated and Conventional Gasoline Programs, 40 CFR Part 80. 76 F.R. 44406, July 25, 2011.

specifies the labeling to be exhibited on pumps at retail stations with the intent of preventing misfueling.

It is important to note that this EPA rule only addresses mitigating misfueling in the event that E15 is lawfully introduced. It does not address waiver conditions or the implementation thereof nor does it address any other questions about the lawfulness of selling E15. Furthermore, fuel and fuel additive manufacturers desiring to sell E15 must still provide a misfueling mitigation plan.[49]

4.) Gasoline detergent certification requirements may need to be changed to ensure that additives are effective when used in E15 blends. Today's detergent additives have been certified on the basis of tests using gasoline containing no more than 10 percent ethanol. As such, current certified additives have not been tested with gasoline/ethanol blends containing more than 10 percent and up to 15 percent ethanol by volume. Certification requirements may need to be changed with respect to any new gasoline detergents and to have currently approved gasoline detergents retested for compatibility with E15 blends. It is not yet clear how EPA will address this issue.

5.) EPA RVP exemption regulations are written for gasoline containing ethanol between 9 percent and 10 percent by volume. EPA has ruled that under the Clean Air Act[50] it does not have authority to provide this exemption to E15. [51] Such a waiver would require Congress to modify the Clean Air Act. This implies that some areas will require different gasoline blending stock to produce E15 than is used currently to produce E10.

State level regulations

States and local legislation and regulations for fuel properties, as well as ASTM and NIST specifications for gasoline, currently exist.[52] However, these regulations vary markedly from state to state and did not contemplate E15 blends. In general, the following regulatory issues will need to be resolved before E15 can be sold in individual states.

1.) States have adopted ASTM and NIST standards that have been written to apply to gasoline and E10, but which were not intended to apply to E15 fuels. Either new ASTM and NIST standards will need to be written and/or states will need to change their regulations.

2.) Some states have enacted legislation and promulgated regulations that mandate fuel specifications and/or provide tax incentives to encourage the use of biofuels. These mandates and tax incentive programs have generally applied to E10, but not to higher percentage ethanol blends. Legislation and regulations will need to be modified for E15 blends so as not to discourage their use.

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[49] Ibid., page 44440.

[50] CAA section 211(h)(4).

[51] 76 F.R. 44406, July 25, 2011, page 44408 and pages 44433-44435.

[52] ASTM International, formerly known as the American Society for Testing and Materials (ASTM), is an organization that facilitates the development and delivery of voluntary consensus standards. NIST, the National Institute of Standards and Technology, is a non-regulatory federal agency that assists the private sector in developing standards.

3.) Many states have adopted their own state-level RVP limits to control gasoline volatility. Similar to the federal regulations, these state regulations will need to be changed to accommodate E15.

4.) California imposes restrictions on fuel properties that extend beyond those required by other states. Currently, California has an E10 blend cap. Commercial use of E15 would require modifications of this blend cap and potentially modification of the standards for other fuel properties as well. Gasoline sold in California is certified using CARB's Predictive Model. Modifying the California Predictive Model to accommodate E10+ blends would require conducting a relatively extensive emission test program.[53]

5.) Introduction of E15 may cause states that are required by federal clean air regulations to file a state implementation plan (SIP) to modify them.

Vehicle Engine Warranties

Vehicle manufacturers have uniformly established E10 as the maximum allowable level of ethanol permissible for use in new vehicles other than FFVs. The Coordinating Research Council is currently conducting a collaborative effort to study the effect of higher ethanol blends on engine performance.[54] In responses to a letter sent to them by Wisconsin Congressman James Sensenbrenner inquiring about their concerns about higher-ethanol blends of gasoline, numerous automotive manufacturers voiced their concerns about the potentially deleterious effect of E15 on engine components.[55] Based on the thirteen automaker responses he received, Congressman Sensenbrenner wrote the EPA Administrator that automotive manufacturers nearly unanimously believe that E15 will damage engines in model year 2001 and later vehicles and negatively affect fuel economy. Because automakers have yet to approve the use of fuels containing more than 10 percent ethanol, drivers who choose to use E15 gasoline would, according to these responses, invalidate their engine warranties.[56] Given the current broadly based concern by automakers, it is not clear if or when automakers will allow the use of E15 under their engine warranties.

Infrastructure Modifications

Introduction of E15 will result in changes to the equipment used to store and deliver the new gasoline blends to consumers.

1.) Since EPA has not granted an RVP waiver for E15, E15 will require a different gasoline blendstock than is used currently for E10 in regions where the waiver is applied. Where a separate blendstock is used for E15, separate tankage will be required at terminals

[53] Sierra Research Report, page 21.

[54] Robert L Grecco III, American Petroleum Institute, written statement before the House Science, Space and Technology Hearing on E15 Research, July 7, 2011.

[55] Letter from F James Sensenbrenner, Jr., Representative, Fifth District Wisconsin, to Lisa Jackson, Administrator EPA, July 5, 2011.

[56] The bibliography contains citations to thirteen letters written by automotive manufacturers and distributors that state their position on the use of E15. They state that for existing vehicles the vehicle warranty will become invalid if the owner uses E15.

and pipelines will need to create separate specifications in order to transport this new blendstock.

2.) For retail stations a key issue is the ability of existing stations to sell E15 without creating a safety or spill problem. Recent test results have identified potential issues with nonmetal components including gaskets and seals.[57] This could affect both dispensing unit and underground storage tanks. Few existing retail outlets are currently prepared to dispense E15. These stations may thus need to replace some existing equipment, but Underwriters Laboratory (UL) has yet to approve any equipment specifically for use with E15. As a result, even if they are able to obtain necessary approvals from local officials such as fire marshals, installing such equipment would violate OSHA regulations, thus creating liability issues for retailers.[58] Similar materials issues could occur at terminals.

As is the case with E85, gasoline station and terminal owners face no obligation to distribute or sell E15 and are thus under no compulsion to invest in making any of the infrastructure changes that may be required to dispense the fuel. As is the case for E85, consumer acceptance of and potential demand for E15 is highly uncertain and independent terminal and retail station operators are unlikely to make such investments unless they are provided with adequate incentives to do so.

4.1.3 Limit neat gasoline sales

Not All Gasoline Contains Ethanol

Two reasons help explain why not all gasoline sold today contains ethanol: consumer preference for use of neat gasoline in certain types of gasoline engines and a lack of distribution infrastructure.

First, many fuel buyers strongly prefer purchasing E0 rather than E10 in markets where both are available; in particular owners of marine outboard engines, older automobiles and motorcycles, and small off-road engines often prefer to purchase E0 because they perceive that E10 can lead to performance problems, particularly in cases where the engines are likely to sit idle for extended periods of time. Ethanol can also shorten the life of rubber gaskets and fuel lines in older engines.

Second, in some terminals and in some areas of the country, transportation and storage infrastructure constraints may limit the amount of ethanol that can be blended into gasoline or

[57] GAO Intermediate Ethanol Blends Report, pages 23-27.

[58] GAO Intermediate Ethanol Blends Report, pages 29-30. In addition, recent EPA guidance states that unless the owner and operator of an underground storage tank (UST) is able to demonstrate that the UST system is made of materials that are compatible with the ethanol (or biodiesel) blend stored, the UST owner and operator may not use the system to store those fuels. UL approval is one acceptable measure of demonstrating compatibility. In the absence of UL standards, a UST owner can demonstrate compatibility by providing a written approval statement provided by the equipment manufacture or by using “another method determined by the implementing agency to sufficiently protect human health and the environment”, although methods for demonstrating compliance by using this third option have not yet been defined. EPA, Office of Underground Storage Tanks, “Guidance On Compatibility Of UST Systems With Ethanol Blends Greater Than 10 Percent And Biodiesel Blends Greater Than 20 Percent”, 76 F.R. 39095, July 5, 2011.

render such blending entirely impractical. Ethanol is blended with gasoline as the product leaves the terminal for retail outlets. At some terminals, restrictions on space prohibit the construction of additional tankage for ethanol.[59] For other locations, transportation costs make the blending of ethanol uneconomic.[60] Overcoming these remaining infrastructure barriers will be costly and time consuming, as the ethanol blending and transportation infrastructure investments that have already been made to date have presumably been concentrated in places where such infrastructure could be added at relatively low cost.

The Market Share for Neat Gasoline (E0) is Unlikely to Decline Sharply from Recent Levels

Tyner estimates the market share for E0 at 10 percent. CRA estimates the market share for E0 using EIA historical data. Figure 1 illustrates the market share of E0 as a function of time. Between mid-2008 and early 2010, the market share of E0 dropped fairly consistently, reflecting the addition of new ethanol transportation and storage infrastructure in terminals and areas that previously had not been equipped to handle ethanol. This steady decline came to an end in 2010; a result that is consistent with the exhaustion of all or nearly all of the “low-hanging” opportunities for adding ethanol infrastructure at relatively modest costs.

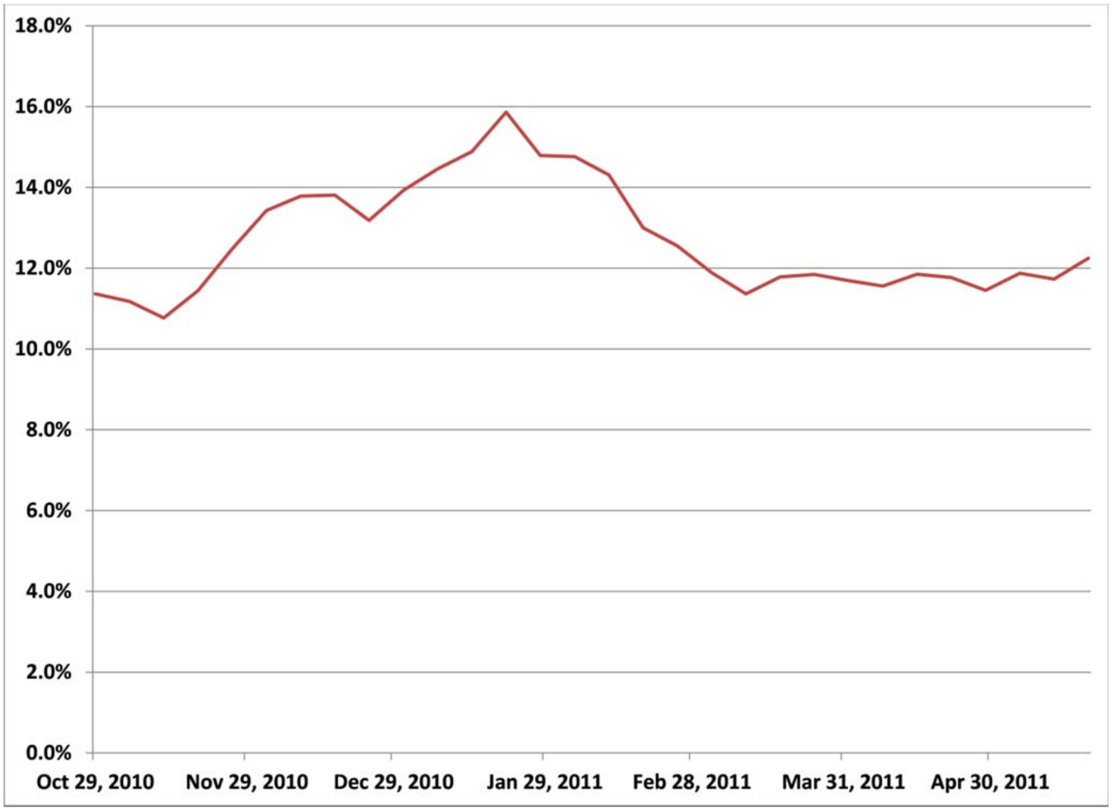
[59] Ethanol is highly miscible in water, while petroleum-based fuels are not. As a result, the pipelines to transport petroleum-based fuels have not been designed to be water-free, and the tankage used to store these products at terminals may contain water as an immiscible layer. Ethanol, however, must be stored in separate dedicated tankage to avoid picking up any of this water.

[60] Most U.S. ethanol is produced in the Midwest and must be transported relatively great distances to those petroleum terminals located on the coasts. In addition, as ethanol or ethanol-blended gasoline cannot be transported in the same pipelines used to transport petroleum products, which are not designed to be water-free, most ethanol is transported in batches by barge, rail or truck to terminals.

Figure 1: Neat gasoline (E0) as a percentage of the total amount of gasoline (% by volume), weekly data for period beginning May 30, 2008

Figure 2, which presents E0 share numbers over roughly the last six months for which data are currently available, even more clearly illustrates that the share of all gasoline represented by E0 has stopped declining. After reaching a record low of 10.8 percent in early November 2010, the weekly E0 market share that we derived from EIA data has varied between just over 11 percent in mid-November 2010 to a peak of nearly 16 percent in mid-January 2011; in data collected this spring, E0 has typically accounted for roughly 12 percent of the total gasoline pool.

Figure 2: Neat gasoline (E0) as a percentage of the total amount of gasoline (% by volume), weekly data for period beginning October 29, 2010



Despite these recent data, there is some reason to suspect that once the blend wall becomes nearly binding, RIN prices will rise enough to encourage further shifts from E0 to E10. Based on these data, we assume that the E0 share of gasoline sales will fall to 10 percent over the next several years. This estimate is conservative in that it represents a decline in the E0 share from its recently recorded levels despite the absence in recent data of any evident downward trend in that share. The estimate is also conservative in that it represents an E0 share that is nearly 1 percentage point lower than has ever been recorded in any particular week (let alone month or year) of historical data and that is roughly two percent lower than E0's share across the most recent several months for which data are available. As a sensitivity analysis, we also analyzed the effect on the blend wall if the share of E0 declines to 5 percent. While recent historical experience provides no evidence that E0's share can be reduced to this level over the next one to three years, we decided to use this lower share as a test of the robustness of our findings against a scenario in which fuel marketers can react to higher RIN prices quickly and are able to execute aggressive actions to eliminate any infrastructure barriers now standing in the way of near-universal E10 availability.

4.1.4 Diesel pool: increase use of biodiesel as blendstock

Introduction and overview

In theory, increasing the quantities of biomass-based fuels used as diesel fuel blend stocks could help delay the date when the E10 blend wall is breached. While the RFS2 program sets minimum annual targets for biomass-based diesel fuel use that are to be enforced by tracking the production and disposition of biomass-based diesel RINs, these requirements are nested under RFS2 program's total renewable standard requirements. Consequently, an obligated party can apply any biomass diesel RINs in excess of those needed to meet its biomass-based diesel obligations under the total renewable fuel standard.[61] In practice, the number of biomass diesel RINs that may be available to help forestall reaching the blend wall will depend on the existence of any near-term constraints limiting the quantities of biomass-based diesel fuels that can be produced, distributed, and consumed in the United States and how readily those constraints might be overcome.

The remainder of this section considers various such constraints and assesses their significance in the context of the volumes of biomass-based diesel fuel that will be needed to forestall reaching the blend wall. The discussion begins with our estimates of these volumes for each of the next several years and an assessment of the types of biomass-based diesel fuels that could be made available on a commercial scale during these same years. After first establishing that the RFS2 program's mandates for biomass-based diesel fuel use are well in excess of historical U.S. consumption and production levels, the discussion then proceeds to an assessment of potential barriers that might prevent the quantities of biomass-based diesel fuels from growing well beyond these mandated levels quickly enough to forestall reaching the blend wall.

How much biomass-based diesel fuel will be needed to overcome the E10 blend wall?

The model we used to predict when the blend wall will become binding can also be used to estimate the total volumes of biomass-based diesel fuel consumption that would be required in any given year to avoid breaking the E10 blend wall and satisfy that year's RFS2 total renewable fuels target.[62] Our estimates for the years 2011 through 2015 are reported below in Table 4, along with the AEO2011 forecast of biodiesel consumption in those years.

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[61] Biomass-based diesel RINs are reported in ethanol-equivalent RINs by applying an EPA-specified "equivalence value" that reflects the ratio of the energy content in a gallon of a biomass-derived diesel fuel to the energy contained in a gallon of ethanol. For the conventional biodiesel fuel most commonly used today, so-called FAME biodiesel, EPA has set an equivalence value of 1.5; i.e., each gallon of FAME biodiesel generates 1.5 ethanol equivalent RINs for purposes of compliance.

[62] This estimate takes into account CRA's estimate of the maximum volumes of E85 that are likely to be sold in the absence of new price subsidies for that fuel and sets the volumes of E0 at 10 percent of the combined total sales of E0 and E10.

Table 4: Estimates of biodiesel volumes required to satisfy the RFS2 total renewable fuel target (billions of gallons)

Year	Required biodiesel volume	AEO2011 biodiesel consumption forecast	Amount required above AEO2011	EPA biomass-based diesel volume standard	Amount req. above EPA biomass-based diesel volumes
2011	0.81	0.68	0.13	0.80	0.01
2012	1.5	0.90	0.60	1.0*	0.50
2013	2.1	0.97	1.1	1.3*	0.80
2014	2.8	0.97	1.8	1.3†	1.50
2015	4.0	1.2	2.8	1.3†	2.70

*Proposed

†EPA will set in a future rulemaking; assumed to remain at proposed 2013 level (1.28 billion gallons)

EPA proposed the RFS2 volumes for the biomass-based diesel mandates at 1 billion gallons for 2012 and at 1.28 billion gallons for 2013. If the RFS2 target for biomass-based diesel in 2012 can be met, the increment to biomass-based diesel fuel sales that would be required to meet the total renewable standard would be another 500 million gallons. The challenge stiffens every year thereafter. In the year 2013, the industry would need to sell 2.1 billion gallons of biodiesel in total, 800 million gallons in excess of the volumes required to meet the proposed biomass-based diesel standard and 1.13 billion gallons more than the EIA forecasts will be used in that year. Under the assumption that EPA will again propose biomass-diesel volumes at the 2013 level (1.28 billion gallons) for years 2014 and 2015, the increments to projected sales are more than 1.5 billion gallons and 2.7 billion gallons, respectively.

"FAME" biodiesel is the only biomass-based diesel fuel likely to be available in significant quantities over the relevant time horizon

There are three distinct categories of biomass-based diesel fuel identified in the RFS2 regulations: "biodiesel, "renewable diesel," and "cellulosic diesel". In theory any combination of these fuels could be used to satisfy either the RFS2 biomass-diesel standards or the total renewable fuels standard,[63] in practice though, only biodiesel fuel is likely to be available for sale in appreciable quantities during the time horizon in which the ethanol blend wall will become binding.

Biodiesel fuel is produced from plant or animal fats through a chemical process called transesterification; the most commonly produced form of biodiesel is composed of fatty acid methyl esters (FAME). These fatty-acid esters are chemically distinct from the pure hydrocarbon chemical species that make up petroleum-based diesel fuels, and possess different physical characteristics as well (e.g., energy density, cloud point, pour point,

[63] Cellulosic diesel fuel also generates cellulosic RINs that can be used to satisfy the RFS2 program's cellulosic biofuels requirements. Cellulosic diesel and renewable diesel fuels have a greater energy density than do "biodiesel" fuels; consequently, they carry a higher equivalence value (1.7) than does biodiesel fuel (1.5) for purposes of generating renewable fuels standard RINs.

viscosity, lubricity, etc.). Such is not the case for the other two categories of biomass-based diesel fuel. Renewable diesel is also produced from plant and animal fats, but, unlike FAME, it is produced using a hydrotreating process that yields a pure hydrocarbon fuel that is essentially indistinguishable from petroleum-based diesel fuel. Cellulosic diesel, too, is a pure hydrocarbon fuel; it can be produced using a BTL process that effectively converts plant cellulose into a mixture of pure hydrocarbons.

The production technology for FAME biodiesel is mature and it also requires far less capital than either of the other two processes. FAME has been, and likely will continue to be, the predominant biomass based diesel fuel in use over the next several years, if not decades. Historical production of renewable diesel has been miniscule, and RFS2 regulations do not allow renewable diesel that is co-processed with petroleum-based fuels to qualify as biomass-based diesel fuel. [64] The Regulatory Impact Analysis prepared in connection with the EPA RFS2 ruling cites only one likely near-term addition to U.S. renewable diesel capacity, a new plant opened this fall in Geismar, Louisiana by Dynamic Fuels, LLC that has an output capacity of 75 million gallons per year. More than two years elapsed between the start of construction of the plant and the start of production, which suggests that another plant would already have to be under construction for renewable diesel fuel to account for any greater volume of fuel over the next one to two years. Indeed, the EIA's most recent forecast for the consumption of renewable feedstocks used for the on-site production of diesel and gasoline is flat through the year 2020 at roughly 10 trillion Btus per year, [65] or approximately 77 million gallons of renewable diesel feedstock. Cellulosic diesel fuel has not yet been produced in the U.S. in any commercial quantities, and no one has yet announced any firm plans to do so.[66] Given the required lead-times and the absence of any announced plans to build additional facilities of either alternative type, we assume that for the next several years at a minimum, any incremental volumes of biomass-based diesel fuel used to satisfy the RFS2 program's total renewable fuels obligation would be FAME biodiesel.

The RFS2 program mandates biomass-based diesel fuel consumption that greatly exceeds historical norms

The RFS2 program's targets for biomass-based diesel fuel consumption are 800 million gallons for 2011 and 1 billion gallons for 2012. As the historical data displayed below in Table 5, these levels are already well in excess of the amounts of biodiesel fuel that have ever been produced or sold in the U.S. in any year before the RFS2 program came into being. The 1 billion gallon target for 2012, for example, would require U.S. consumption to almost triple from the levels typically recorded between 2007 and 2009. The target also represents almost half again as much biodiesel fuel as had ever been produced in the U.S. in any year before the RFS2 program came into force.

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[64] ''Biomass-based diesel'' excludes renewable fuel derived from co-processing biomass with a petroleum feedstock." 75 F.R. 14670, March 26, 2010, page 14686.

[65] EIA AEO2011, Table17, Renewable Energy Consumption by Sector and Source, Reference case ", line 23.

[66] Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards, A Proposed Rule, 76 F.R. 38844, July 1, 2011, Table I.A.1-1, page 38847. "RFS Hearing: Biofuel Groups Want Certainty, Refiners Want Real-World Data", http://www.opisnet.com/rfs2rins/headlines.html, July 12, 2011.

Table 5: Historical and Projected 2011 U.S. Biodiesel Production and Consumption
(million gallons)

Year	Production	Consumption
2005	91	91
2006	250	261
2007	490	358
2008	678	316
2009	506	317
2010	309	221
2011 (proj.)	713	705

Sources: Historical data from EIA Monthly Energy Review, July 2011, Table 10.4.; 2011 projection from EIA Short Term Energy Outlook, September 7, 2011 release.

Even just meeting the RFS2 program's biomass-based diesel standards will thus require increasing biodiesel consumption to levels well beyond any seen before -- and doing so in a period of only one to two years. It is thus questionable to expect biodiesel consumption to increase over the next few years to the very high levels required to forestall encountering the blend wall. To explore whether such an outcome is feasible, the following sections assess potential barriers to expanding biodiesel consumption and production and whether they are likely to limit the fuel's near-term opportunities for growth.

Potential demand-side barriers to increasing consumption

We first consider whether there are any significant barriers that may limit the volumes of biodiesel that buyers of transportation fuels are prepared to purchase. While such barriers may exist, we cannot find any evidence to suggest that any are significant, at least until the percentage of biodiesel in the U.S. diesel fuel pool begins to approaches 5 percent. Barriers in production and transportation are likely to represent more serious impediments to increased use of biodiesel fuel.

The B5 blend limit

Most biodiesel fuel is consumed in blended diesel fuels in which petroleum-based diesel fuel constitutes 95 percent or more of the blend by volume. The most common of such blends are B5 (5 percent biodiesel by volume) and B2. Some biodiesel is also consumed in blends containing up to 20 percent biodiesel fuel (B20), and even smaller amounts are consumed as neat biodiesel fuel (B100). While several diesel engine manufacturers and automakers permit the use of B20 blends in engines and vehicles that are in use today, the National Biodiesel Board's most recent summary of manufacturer recommendations indicates that many manufacturers continue to recommend the use of only B5 or lower percentage blends[67] These requirements effectively create a B5 blend limit that is analogous to the E10 blend wall. Fueling stations that wish to provide at most one diesel fuel blend of any grade are thus limited to B5 or lower biodiesel blends. We estimate that the diesel fuel pool would approach the B5 blend limit in 2013 and exceed it by 2014 in actions that rely on increasing biodiesel use in transportation fuels as the primary response to avoid reaching the E10 blend wall. It may be possible, however, to overcome potential customer resistance (such as might arise from the lower fuel economy provided by biodiesel blends) and include higher percentages of biodiesel into the fuels sold in rail or military applications. In addition, the RFS2 regulations also permit RINs to be created not only when biodiesel is blended into motor fuel, but also when biodiesel fuel is blended into #2 heating oil or kerosene. Depending on how much biodiesel fuel these product streams can absorb, or the fuel infrastructure can deliver, the B5 blend limit for transportation fuel may be slightly delayed by up to a year, or potentially beyond 2014.

Consumer acceptance issues

Even though no formal barriers prevent the overall diesel fuel pool from reaching up to 5 percent biodiesel by volume, customer acceptance issues might conceivably do so. Because biodiesel fuel is less energy dense than petroleum-based diesel fuel, fuel buyers may see a decrease in fuel economy after switching to a biodiesel blends, although the decrease is likely to be hard to measure when switching from neat petroleum-based diesel fuel to a B5 or another low biodiesel blend. The known risks to engine durability and performance associated with the use of diesel fuels containing high percentages of biodiesel might deter some consumers, but the use of B5 and lower biodiesel blends should not be problematic. For purposes of our analyses, however, we assume that consumer acceptance issues will not impede more widespread use of biodiesel fuel in the form of B5.

Potential barriers to increasing production

Available biodiesel production capacity should be able to support higher production levels and additional capacity can be added if needed

Historically, U.S. biodiesel plants have run at very low average utilization rates, with capacity far outstripping total domestic demand and net export demand. To date, the economics of biodiesel production have been heavily dependent upon biodiesel fuel receiving an excise tax credit. The industry's experience in 2010, a year in which the excise tax credit was allowed to lapse before being reinstated on a retroactive basis, provides evidence for this point. Facing no guarantee that the excise tax credit would be reinstated, biodiesel producers responded by producing far less biodiesel fuel in 2010 than they had in any of the three immediately preceding years.

The biodiesel production capacity that nominally exists in the U.S. appears to be more than sufficient to accommodate the demand for biodiesel fuel created by RFS2 biomass-based

[67] Firms that place a B5 limit on the biodiesel content in recommended fuels on at least some engines or vehicle models include Chrysler, Ford, General Motors, Mercedes Benz, Volkswagen, Detroit Diesel, Caterpillar, and International Harvester. National Biodiesel Board, "Automakers' and Engine Manufacturers' Positions of Support for Biodiesel Blends as of September 2008".

diesel standards. *Biodiesel Magazine* reports that U.S. biodiesel processing plants in existence today have nameplate capacity exceeding 2.8 billion gallons, although an unknown share of that capacity may now be utilized to produce fatty acids used in other industrial applications such as the production of soaps and surfactants. Another approximately 400 million gallons of additional capacity is reportedly now under construction in the U.S.[68] The historical record has shown that biodiesel production plants can be built on a relatively small scale with relatively small amounts of capital required and that, as a result, producers have quickly been able to add new capacity whenever federal tax and subsidy policies provided sufficient incentives to justify the additions. These same conditions would support further additions to biodiesel production capacity if RIN prices rise to sufficiently high levels as a result of the steadily increasing RFS2 renewable fuels targets. For these reasons, we conclude that a lack of plant capacity is unlikely to serve as a binding constraint to increasing biodiesel production in the near term.

Feedstock availability at affordable prices will be a barrier to expanded production

Although biodiesel fuel can be, and is, produced from any number of animal, vegetable, and waste feedstocks, soybean oil is the most important feedstock used to produce most of the biodiesel fuel in the U.S. today, and is likely to remain the dominant U.S. biodiesel feedstock for the foreseeable future. Soybean oil and all of the other vegetable oils and animal fats used as biodiesel feed stocks however, are valuable commodities that have many other uses – not only as foods but as raw materials used to produce manufactured goods. Thus, the availability of potential biodiesel feedstocks will be limited not only by constraints in crop acreage and yields, but also by the substantial demand for potential feedstocks in these other uses. In addition, virtually all of the feedstocks for U.S. biodiesel production will need to be sourced domestically, as domestic demands should constrain oil seed producing countries from providing significant product volumes to the United States.[69]

Even before taking these other uses into account, the resource base available to support U.S. biodiesel production is limited and could, at best, displace only a small fraction of the diesel fuel now consumed in transportation. An estimate published in 2008, for example, notes that even if the entire 36.9 billion pound supply of fats and oils available in the U.S. in 2007 had been converted into diesel fuel, the resulting biodiesel volumes would have been sufficient to replace only 12 percent of the then 39-billion-gallon U.S. demand for on-highway diesel fuel.[70]

The resource base available to support U.S. biodiesel production in the near term will, of course, be only a fraction of the total supply of animal and vegetable fats. In a 2009 report, Alan Weber, an industry consultant and an adviser to the National Biodiesel Board, reviewed the likely availability of feedstocks to support biodiesel production in 2012. He concluded

[68] http://www.biodieselmagazine.com/plants/listplants/USA/, accessed May 26, 2011.

[69] An additional hurdle to imports is the requirement for importers to demonstrate that foreign feedstocks meet the definition of renewable biomass, and that the biofuel manufacturer is registered with the USEPA.

[70] Jon Van Gerpen, Allan Gray, and Brent H. Shanks, “Convergence of Agriculture and Energy: III. Considerations in Biodiesel Production”, CAST Commentary QTA2008-2, October 2008. (Available at http://digitalcommons.unl.edu/usdaarsfacpub/290/; accessed June 15, 2011.)

then that more than 1.8 billion gallons of potential feedstocks would likely be available in 2012, consisting of approximately 750 million gallons of soybean oil, 200 million gallons of oil from high oil content oilseeds such as camelina and canola, 400 million gallons of corn oil feedstock from U.S. ethanol plants, and more than 400 million gallons of animal fats and yellow grease.[71] Achieving some of these estimated volumes would require biodiesel producers to acquire substantial volumes of feedstocks in direct competition with other potential uses.

As an example, producing 750 million gallons of soybean oil feedstock would require producers to obtain the oil from about 30 percent of the U.S. soybean crop, placing upward pressure on soybean oil prices.[72] Another Weber estimate of likely resource availability in 2012 now seems greatly optimistic or even unachievable given the conditions that now prevail in 2011.[73] Weber's 1.8 billion gallon estimate thus almost certainly overstates the amount of biodiesel feedstocks that are likely to be available to U.S. producers in 2012, and should provide a conservative upper bound on the amount of feedstocks that will be available to biodiesel producers over the next one to two years. It thus appears that while there might be enough feedstock available to U.S. biodiesel producers in 2012 to support the level of production (1.5 billion gallons) that we estimate would be required that year to forestall reaching the blend wall, by 2013 there will not be sufficient feedstock volumes available to

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[71] J Alan Weber, "Feedstock Supplies for U. S. Biodiesel Production", MARC-IV Consulting, Inc., January 2009, p. 2. Weber's report also includes a cursory discussion of "additional potential near-term sources" of biodiesel feedstock, which Weber claimed could make available up to another 2.5 billion gallons to US biodiesel producers by 2012. The availability of any of these additional potential resources by 2012 was highly speculative when Weber issued his report in 2009, as achieving any of them would have required making fundamental changes in technology or established business practices over a period of only three years. From today's perspective, none of these changes could realistically be achieved in the less than one or two years that CRA estimates might remain before the E10 blend wall is reached.

[72] Devoting substantially more acreage to soybean production is probably only a limited possibility as soybeans compete with corn for available land in much of the country, and the economics of ethanol production are such that corn dominates soybeans as an energy crop. For example, in 2007 a study by researchers at Iowa State concludes that

> "Cellulosic ethanol from switchgrass and biodiesel from soybeans do not become economically viable in the Corn Belt under any of the scenarios. This is so because high energy costs that increase the prices of biodiesel and switchgrass ethanol also increase the price of corn-based ethanol. So long as producers can choose between soybeans for biodiesel, switchgrass for ethanol, and corn for ethanol, they will choose to grow corn."

Simla Tokgoz, Amani Elobeid, Jacinto Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Hsiang (Edward) Yu, Fengxia Dong, Chad E. Hart, and John C. Beghin, "Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets", Iowa State University Center for Agricultural and Rural Development, Staff Report 07-SR 101, May 2007, page 1.

[73] Producing an additional 200 million gallons of canola oil, for example, would require U.S. farmers to devote almost three times as much acreage to canola production as they did in the 2010-2011 season. In addition, achieving Weber's 400 billion gallon estimate of the volumes of corn oil to be supplied by corn ethanol would likely require about half of US ethanol plants to incorporate relatively efficient corn-oil extraction technology into their plant, while industry observers estimate that only about one-third of U.S. ethanol plants are equipped to extract corn oil today, and many of these plants use relatively low-yield technologies.

U.S. biodiesel producers to support the higher production level (2.1 billion gallons) that we estimate would be required to avoid reaching the blend wall in 2013.[74]

Barriers in transportation, storage and distribution

Even if sufficient volumes of affordable feedstock and processing capacity could be found to produce enough biodiesel fuel to avoid the E10 blend wall, fuel producers and distributors would still need to make significant investments to make the additional biodiesel production available to consumers in the form of blended diesel fuels. The process of acquiring and installing the infrastructure needed to transport, store, and blend biodiesel fuel is likely to place its own sets of limits on how much and how quickly biodiesel fuel consumption can grow over the next few years. Most of the infrastructure issues that could impede growth in biodiesel fuel consumption are even more complicated than the issues that complicate adding large additional volumes of ethanol for use in blended transportation fuels. These include the need to add capacity to move B100 blend stock from production plants to terminals and the need for terminals to provide tanks dedicated to storing B100 capable of holding the fuel above its gelling point on a year-round basis.

Transportation

While at least some biodiesel production capacity can be found in 42 of the 49 states included in the RFS2 program, a large fraction of biodiesel production capacity is concentrated in a few states and the geographical distribution of plant capacity does not closely match the distribution of the U.S. population.[75]

This imbalance, as is the case with ethanol, means that significant volumes of B100 fuel will need to be transported from plants located in the middle of the country (e.g., those in Texas, Arkansas, and the Midwest states) to terminals serving customers in the Mountain West states and along the East and West Coasts. These fuel volumes will have to be moved by rail, truck, or barge, as B100 and biodiesel blends cannot be transported in any pipeline that also transports jet fuel.[76] Transportation of B100 blendstock is further complicated by the need to keep the fuel at warm temperatures in cold and even cool weather conditions. Biodiesel fuels exhibit far higher cloud point and pour point temperatures than do petroleum-based fuels, and even the most cold-resistant biodiesel fuels must be kept warm in transport, requiring the use of heated or insulated equipment in cold and even cool weather conditions.

[74] If the share of neat gasoline could be reduced to 5% of the gasoline pool, then 1.6 and 2.3 billion gallons of biodiesel would be needed in 2013 and 2014, respectively. .

[75] In particular, plants in just two states, Texas (20.6 percent) and Iowa (10.8 percent) account for nearly one-third of US production capacity. By contrast, the states of California, Florida, and New York, which account for nearly one-fourth (24.4 percent) of the U.S. population recorded in the 2010 Census, together accounted for only 4.6 percent of biodiesel production capacity.

[76] Current specifications for jet fuel effectively exclude fuels that contain biodiesel contaminants at any detectible level. Because transporting different fuels in the same pipeline system invariably results in some measure of cross-contamination among them, pipeline transportation of biodiesel fuel is only possible in systems that exclude jet fuel, of which there are very few.

These constraints will require new investments in transportation equipment, such as additional rail cars, barges, and tank trucks and sufficient time to order, manufacture, and install it. It is far from clear that new equipment purchases of the scale required to support the biodiesel volumes that would be needed to forestall reaching the blend wall could be accommodated within just a few years at most, particularly given that the specialized nature of the heated equipment that will be required. In the next two to three years, production would need to increase by three to four times peak production (i.e., 2008 production) in order to comply with the RFS2 and avoid the blend wall. Even if there were sufficient resources available to support these production levels, this rapid increase calls into considerable question whether the necessary transportation equipment could be acquired and installed in time.

Distribution and Storage

As is the case with ethanol, selling additional volumes of biodiesel in blended fuels will require substantial new investments at petroleum terminals. B100 blend stock will need to be stored in dedicated tanks that in many parts of the country will have to be heated. As is the case with ethanol, adding additional dedicated tanks may prove difficult or even impossible at terminals with little unused acreage. Widespread use of biodiesel blends will also require the installation of blending infrastructure at many terminals, as splash-blending biodiesel blends (the current practice at many terminals) presents blend quality concerns and will be impractical on such a large scale, especially in colder climates.

The new infrastructure requirements are likely to be extensive, and will require both time and considerable sums of capital to accomplish. As is the case with the investments in transportation equipment, purchasing and installing the additional equipment that will be needed to increase biodiesel use from peak historical levels to the levels needed to satisfy EPA's proposed biomass-based diesel volume standards will require much new investment to take place in a few short years. The additional infrastructure requirements needed to support the 2-3 times greater increase in biodiesel sales volumes relative to historical peak levels that CRA estimates would be required to forestall reaching the blend wall as soon as 2012 would require overcoming far greater and likely insurmountable challenges.

Conclusions

While the volumes of potential feedstocks available to U.S. biodiesel fuel producers in 2011 and 2012 may be sufficient to allow them to produce the quantities of fuel that will have to be consumed to avoid reaching the E10 blend wall in that year, feedstock resources will likely be insufficient to produce the still larger volumes of biodiesel required to avoid reaching the blend wall in 2013. Even if producing the required amounts of biodiesel proves to be possible in both years, the need to create the transportation and distribution infrastructure required to handle the needed volumes of biodiesel will create its own set of limits on how much fuel can actually reach customers' fuel tanks. The levels of U.S. biodiesel consumption required to forestall reaching the blend wall in 2012 and 2013 are roughly four to six times greater than the consumption levels experienced in 2010 and prior years. On both counts, achieving the volumes of biodiesel sales that we estimate will be required over the next few years to avoid confronting the E10 blend wall appears to be an unlikely, if not an impossible prospect. Consuming more biodiesel fuel is thus not a realistic answer to the question of how the to avoid reaching the E10 blend wall sometime in the next few years.

4.2 The RFS2 rules will encourage fuel sellers to comply by rationing production of some fuels: lessons from economic theory

4.2.1 Other options to confront the blend wall and implications of economic theory

In the first section of this report, we concluded that the blend wall will become a binding constraint in the very near future, possibly as soon as in 2011 and almost certainly by 2013. In the following sections, CRA then considered the feasibility of action that would require new product introductions or dramatic changes in the use of what are today niche fuels -- increasing E85 sales substantially beyond the levels currently projected in EIA's AEO2011 forecasts, introducing E15 as a retail motor fuel, substituting E10 for E0 in circumstances in which the latter fuel remains today's fuel of choice, or increasing the use of biodiesel fuel to levels well beyond those required to meet the RFS2 biodiesel standard -- and concluded that none of these changes could be implemented easily enough or quickly enough to prevent the blend wall from being reached in the next one to two years. With these options ruled out, obligated parties are essentially left only with changes in fuel mix as viable paths to compliance. The next section explains the key features of the RFS2 program that encourage such actions. The sections that follow explain potential options for pursuing such actions and some guidance from economic theory about how decisions on what options to pursue could be made.

4.2.2 The RFS2 program establishes annual renewable fuels obligations on a percentage basis

Annual compliance with the RFS2 regulations does not require obligated parties, either individually or collectively, to obtain RINs to meet the RFS2 program's absolute volumetric targets for renewable fuels use. Instead, the RFS2 program requires these firms to obtain sufficient RINs each year to cover a given percentage of their total sales of gasoline and diesel transportation fuels.

By November of the year proceeding the compliance period, the EPA sets the applicable percentage standards for renewable fuels content for the coming year. Applicable percentage standards are set for four categories of renewable fuels; of these, the total renewable fuels standard is the most important in determining whether the blend wall will be reached. Fuel-specific applicable percentage standards are computed by dividing the specific renewable fuel volumetric target by a contemporaneous forecast of total gasoline and diesel transportation fuel consumption projected for the coming year. Obligated parties must demonstrate compliance with all four renewable volume obligations by the end of February of the year following the compliance period. The renewable volume obligation (RVO) for an obligated party is equal to the product of the applicable percentage standard multiplied by the applicable volume of nonrenewable gasoline and diesel introduced into commerce, plus any deficit carry-over from the previous year. Compliance by the obligated party is demonstrated by providing a sufficient number of retired RINs, including any excess RINs carried over from a prior year. It is also possible to carry a deficit into the following year, which is then added to that year's obligation.

Taken as a whole, the percentage-based method used to compute an individual party's RIN obligations and, the rules for demonstrating compliance create some significant concerns and complications for obligated parties.

1.) Since the obligation is related to the volume of transportation fuel via the applicable percentage standard, an obligated party cannot guarantee compliance simply by increasing the volume of renewable fuels it blends into transportation fuels without also paying attention to total transportation fuel volumes. This results in an increasingly difficult to impossible scenario for producing "extra" RINs that can be carried over to a future compliance period.

2.) The percentage standard for renewable fuels (largely met by various sources of ethanol) is applied to the total volumes of both gasoline and diesel transportation fuels. Because diesel fuel cannot absorb any of this ethanol and, as previously noted, there are limits on how much biodiesel fuel can be introduced into the diesel pool, applying a single standard across to the total sales of both fuels exacerbates the ethanol blend wall. It is for this reason, for example, that the ethanol blend wall becomes binding at a renewable fuels percentage standard that falls well short of 10 percent. The importance of this is that firms can meet an annual target by establishing the proper ratio of RINs to gallons of fuel sold. Since it is possible to change the ratio by changing either its numerator (RINs) or its denominator (gallons sold), a firm that wants to come into compliance can do so either by increasing its supply of RINs (the numerator) to cover the firm's planned sales volumes or by decreasing gallons sold (the denominator) to match its available supply of RINs. As will be discussed below, economic theory suggests that firms will in fact pursue both of these options to some degree, balancing each against the other on the basis of their costs at the margin.

3.) For purposes of complying with the total renewable fuels standard, ethanol biofuels, regardless of feedstock or source, are fungible within the transportation fuel pool.

4.) Since the compliance period is one calendar year and non-compliance is not a viable business plan, the impacts of hitting the blend wall could hit rather abruptly, at the beginning of the compliance period.

4.2.3 The volume mix of conventional fuels will change

Because an obligated party's RIN obligations are determined on a percentage rather than an absolute basis, obligated parties will favor actions that increase the average percentage of renewable content in the obligated party's combined gasoline and diesel pools. Such actions can include changing the relative mix of conventional fuels that the obligated party chooses to produce and sell so as to increase the sales of higher renewable content conventional fuels and to decrease the sales of lower renewable content fuels.

In particular, obligated parties can take actions to decrease overall sales of transportation fuels that generate no RINs (such as E0 and petroleum-based diesel fuel) and at least in the earliest years after the blend wall is reached, by increasing overall sales of E10. Pursuing these actions, however, will be complicated by the fact that while the firms subject to the RFS2 obligations can independently decrease the volumes produced and then sold of some products (e.g., diesel fuel), the same firms cannot unilaterally increase the sales of other fuels, such as E10 or E85; instead relying on downstream (and largely independent) blenders and retailers to sell more of them. The refiner cannot influence these sales simply by adjusting the wholesale price of gasoline, as it cannot control the blends (e.g., E0, E10, or E85) that its downstream customers will choose to make with the gasoline they acquire. Instead, refiners will have to rely on the value that downstream parties can earn by generating RINs to incentivize these firms to generate additional sales of fuels that generate surplus RINs, i.e., those that have higher ethanol content than is required on average by the percentage target for renewable fuels set by EPA.

4.2.4 Cutting sales of some fuels as a compliance measure and the "death spiral"

If, as discussed above, should shifting neat gasoline consumers from E0 to E10 or E85 and shifting FFV owners from E10 to E85 prove inadequate to overcome the blend wall and to meet the EPA's annual percentage standards for renewable fuels content, then firms may have to choose to restrict their overall sales of E0 and diesel fuels. The ensuing higher consumer costs would serve to ration demands for these fuels to match the available supplies. Higher diesel fuel costs would increase the costs of freight transportation, leading to lower consumption of freight transportation services, and higher costs for goods and services that ultimately would be reflected in higher consumer prices across a wide range of goods and services. In addition, to the extent that household consumers also might see their weighted average cost of transportation fuels increase as a result of higher costs for some fuels, this option for complying with RFS2 would reduce the amount of discretionary spending that consumers have available to devote to purchases of other goods and services.

Production-reducing compliance options will become increasingly difficult to implement over time as the EIA incorporates their effects in its forecasts of future fuel consumption and as target volumes for total renewable fuel use increase.[77]

The most recent EIA forecasts project that the total consumption of gasoline will be fairly flat in coming years as the EIA projects that increases in the fuel economy of new vehicles coupled with fleet turnover should offset any demand increases created by increases in vehicle miles travelled. EIA projects that diesel fuel sales (specifically due to consumption by freight trucks) will increase with economic growth. But the overall growth in fuel consumption projected by EIA is less than the growth in RFS2 targets. As the volume of renewable fuels required under the RFS2 program increases each year this trend by itself implies that the RFS2 renewable fuel percentage share requirement established annually by EPA should experience steady increases from year to year.[78] Should sales of fuels also fall below EIA's forecast levels as firms opt to cut sales of some fuels to achieve compliance with the annual RFS2 standard, EIA will observe this decline in its market monitoring and would have to reduce its forecasts for transportation fuel consumption in the next year. Because the RFS2 mandate is stipulated on a volume basis, this will cause EPA to set even greater market share targets for renewable fuels than it would have set had the EIA's consumption forecasts

[77] In EPA's percentage standard mathematical formula, the numerator (biofuel volume) steadily increases from year to year relative to the denominator (gasoline and diesel fuel consumed), resulting in an ever-increasing percentage standard. If the denominator also shrinks as projected fuel drops, annual percentage standards will increase still more rapidly.

[78] This trend may be made worse by underlying shifts in demand, as EIA is currently forecasting relatively flat demand growth for gasoline.

not been reduced. The tighter percentage standards, in turn, could lead to the need for still larger cuts in the production of E0 and diesel fuels, putting downward pressure on refinery utilization.

The process of repeated cuts in production, fuel cost increases, and lower sales volumes being incorporated into EIA forecast updates creates the conditions for a "death spiral" in which production and sales restrictions in one year create the conditions for far greater production and sales restrictions the next year. These restrictions will put intense upward pressure on consumer prices and create excess capacity in the fuel supply system.[79]

4.2.5 Increasing E10 (and E85) sales levels as a compliance option

Another compliance option available to firms subject to the RFS2 standards is to attempt to increase the sales of fuels that contain a higher percentage of renewable content than the average percentage content applicable to total sales of gasoline and diesel fuel that is set for that year by the EPA. E10 qualifies as such a fuel in the earliest years of the RFS2 program, as the percentage standard applicable to the total sales volumes of gasoline and diesel transportation fuels should require less than 10 percent renewable content on average for at least the next several years.[80] In these circumstances, encouraging consumers (through lower prices) to buy additional gallons of E10 beyond the sales levels assumed in the EIA/EPA forecast facilitates compliance with the total renewable fuels standard. This is because so long as the RIN obligation has been set at under 10 percent of volumes of all transportation fuels sold, the number of RINs that are generated when ethanol is blended into each additional gallon of E10 that is sold is greater than the smaller RIN purchase obligation associated with the sale of that gallon.

It should be noted, however, that the usefulness of this compliance measure is limited both in scope and in time. Even in the very earliest years of the program, the ability of obligated parties to increase E10 sales will be limited by the responsiveness of demand for gasoline to changes in price, which many economic studies have shown to be quite low, especially in the short-run.[81] In addition, the net RIN generation associated with each additional gallon of E10 will steadily decline each year as the average percentage standard for renewable content

79 "Death spiral" refers to an unstable situation wherein the actions taken to comply with a mandate in one year have a negative impact on the industry required to comply and result in the need to take even more severe actions in subsequent years that erode even further the viability of the industry and eventually lead to its demise.

80 The blend wall will be reached well before the total required renewable content across the gasoline and diesel fuel pools exceeds 10 percent. The reason for this outcome is that the limited ability of the diesel fuel pool to absorb substantial volumes of biodiesel effectively requires the gasoline pool to "make up the difference" by incorporating higher levels of renewable content than the EPA-mandated percentages that will be applied to the combined volumes of gasoline and diesel transportation fuels. CRA estimates that the renewables percentage standard applied to the combined gasoline and diesel pools will first exceed 10 percent in 2015.

81 See, for example, see the results of two "meta-analyses" which survey, summarize, and synthesize numerous other economic studies that have estimated the own-price elasticity of demand for gasoline. Phil Goodwin, Joyce Dargay, and Mark Hanly, "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review," *Transport Reviews*, 24(3) (2004): pages. 275-292, and Molly Espey, "Explaining the Variation in Elasticity Estimates of Gasoline Demand in the United States: A Meta-analysis", *Energy Journal*. 17(3) (1996), pages. 49-60.

applicable to the combined diesel and gasoline pools gradually approaches 10 percent. Finally, once the standard exceeds 10 percent, increasing sales volumes of E10 will cease to aid in compliance, and each additional gallon of E10 sold will, on net, increase an obligated party's RIN deficit.

4.2.6 Both sales-reducing and sales-increasing compliance options are likely to be used in combination

Economic theory suggests that a firm attempting to manage its compliance with the total renewable standard should rely on a combination of both these compliance options, seeking to equate the costs to the firm of each compliance option on the margin. Supply-side constraints, such as the limits that refinery and petroleum feedstock characteristics may place on how much more gasoline (for use as E10) can be produced while the firm is also attempting to limit diesel fuel production, will be factors in determining the costs of each compliance option.

These supply side constraints could be eased somewhat if firms are able to decouple production volumes of diesel fuel from sales volumes by exporting surplus production of diesel fuel. The extent to which refiners will choose to pursue export strategies will be determined by the marginal profits that they could earn by selling additional units of gasoline domestically and additional gallons of diesel fuel in export markets against the added costs incurred in producing, and transporting these units. In general, the ability to export surplus domestic production of transportation fuels provides domestic refiners with some added flexibility and may postpone (but not avoid) the eventual emergence of the "death spiral' scenario described in Section 4.2.4.

On the demand side, the changes in the costs paid by consumers for various fuels after relative supplies are changed will also factor into the marginal costs of pursuing each compliance option.

4.2.7 Relative consumer costs will change; E0 and diesel fuel will cost more and E10 (and E85) will initially cost less than these fuels would have cost if the RFS2 limits were not binding

Economic theory suggests that the production and supply of fuels for sale that exceed the overall RFS2 percentage standard for renewable fuels content (like E10 in the early years of the program and E85 in all years) should increase above the "but-for" levels that would have prevailed in the absence of a binding blend wall constraint; at the same time the volume of fuels offered for sale that fall short of meeting the average renewable fuels percentage standard (like petroleum-based diesel fuel or E0) should decrease relative to but-for sales levels. Except for reduced diesel fuel production, which is under the direct control of refiners, the mechanism by which these changes in the volumes of products offered for sale will be driven by the supply and demand of RINs and the resulting incentives for downstream fuel blenders to produce more of those products that, in a given compliance year, are net generators of RINs and less of products that are net RIN sinks.

As a result of these supply changes, the cost to the consumer for E10 will, at least initially, for a period of a few years be lower than it otherwise would have been, and the costs to the consumer for diesel fuel and for E0 will be higher than they otherwise would have been in the absence of a binding blend wall constraint. Thus, diesel fuel and E0 purchasers collectively can expect to bear more than 100 percent of the overall consumer cost burden created by the RFS2 program, while users of E10 will benefit from an implicit subsidy encouraging them to buy higher fuel volumes in early years of the program. The exact magnitudes of the changes in product quantities and cost to the consumer that will result from these supply changes will depend on factors including the relevant own- and cross-price elasticities of demand for the various fuels and the degree to which they can be substituted for one another in production.

It is not clear, though, that such changes alone can forestall the blend wall at acceptable cost for very long. For example, based on the same data as used to derive our estimates of when the blend wall would become binding, we estimate that meeting the percentage-based total renewable standard in 2012 only through changes in E10 sales would require selling 6.9 billion additional gallons of E10 above forecasted levels in an E10-only option, or selling a total of 6.7 billion fewer gallons of E0 and/or petroleum-based diesel fuel in a compliance option that attempts only to limit the sales of such fuels (These figures represent an increase of roughly 5 percent more gasoline than is now reflected in the EIA forecast for 2012, a decrease of as much as 15 percent in the total projected diesel fuel or up to 48 percent of our estimate of the total volume of E0 likely to be sold in 2012). While the likely firm compliance options and market responses would almost certainly involve pursuing a combination of both these compliance options and thus generate somewhat smaller swings in the sales of particular fuels than these numbers might indicate, achieving even seemingly relatively modest percentage changes in fuel sales implied by these estimates will produce fairly substantial changes in the relative prices of these fuels. These relatively large price swings that will result are a product of the highly inelastic demands exhibited by transportation fuels, particularly in the short run.[82] The feasibility of pursuing such compliance options will become more difficult with every passing year as the percentage targets for total renewable fuel use increase each year. By 2014, the changes in fuel sales volumes required to meet the standard are more than three times larger than those needed in the prior year, implying very large changes in production and still greater adjustments in the relative costs to consumers of the various fuels.

4.2.8 Conclusions

Because the RFS2 program is administered through percentage targets, rather than volumetric standards, an obligated party can achieve compliance by managing the shares of various high-renewable-content and low-renewable-content fuels within its product portfolio. Economic theory suggests that obligated parties will opt to pursue such compliance options, reducing their sales of low renewable content fuels, like E0 and diesel fuel and encouraging greater consumption of high renewable content fuels like E85. The costs to consumers of various fuels will adjust to reflect the cumulative effects on fuel supply of obligated parties' individual decisions to adopt these measures, As a result, the costs to consumers of E0 and

[82] The elasticity of demand of gasoline is defined as the ratio of the percentage change in demand for gasoline to the percentage change in the price of gasoline. The short-run demand elasticity for gasoline is about -0.20, which means that it takes a 10% increase in gasoline prices to induce a 2% reduction in demand.

diesel fuel will be higher and the cost to consumers of E85 should be lower relative to the costs to consumers that would have prevailed in the absence of the RFS2 program.

In the earliest years of the program, obligated parties will also have incentives to increase their sales of the E10 fuel used in conventional gasoline-powered vehicles as an additional, but by no means by itself sufficient, means of facilitating compliance. The usefulness of this action will fade over time, however, as the overall percentage target for renewable content in the combined gasoline and diesel pools approaches 10 percent; later, when the RFS2 renewable fuels percentage content target comes to exceed 10 percent, this situation will reverse itself, and obligated parties will face incentives to limit their sales of even E10. The per-gallon costs for E10, as with other fuels in common use today will increase as a result. Overall sales levels of these conventional fuels will drop to levels that can be supported by the available supply of RINs generated by sales of E85 or other fuels with relatively high renewable content.

As actual fuel sales volumes decline, the EIA can be expected to lower its forecasts of future fuel consumption. As EIA forecast volumes are used by the EPA as the denominator in the annual process of setting RFS2 renewable fuels percentage targets, these declines would, under current rules, lead the EPA to set more stringent percentage targets for renewable fuels content than it might otherwise have adopted. The tighter percentage standards, in turn, would present obligated parties with few choices other than to adopt still tighter restrictions on the availability of conventional transportation fuels. The logical consequence of this sequence of events is an ongoing “death spiral” in which production and sales restrictions in one year create the conditions for far greater production and sales restrictions the following year. These restrictions will put intense upward pressure on the costs consumer will face for conventional fuels and create excess capacity in the fuel supply system.

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