

January 2014
14-PB 17

Feasibility and Cost of Increasing US Ethanol Consumption Beyond E10

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Published by the Center for Agricultural and Rural Development, 578 Heady Hall, Iowa State University, Ames, Iowa 50011-1070; Phone: (515) 294-1183; Fax: (515) 294-6336; Web site: www.card.iastate.edu.

Partial support for this work is based upon work supported by the National Science Foundation under Grant Number EPS-1101284. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. This paper benefited from discussions with participants at departmental seminars at Oregon State University and University of the Republic, Uruguay.

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Executive Summary

The proposed decision by the Environmental Protection Agency (EPA) to reduce biofuel mandates that can be met by ethanol to about 13 billion gallons is predicated in part on a finding that consumption of ethanol is largely limited to the amount that can be consumed in E10, a blended fuel containing 10 percent ethanol. One way to increase ethanol consumption beyond E10 levels is with E85, which contains up to 83 percent ethanol. Historical consumption of E85 provides a poor predictor of the level of possible consumption because the price of E85 has never been low enough to save owners of flex vehicles money. We use a new model of E85 demand to estimate the feasibility and cost of meeting higher ethanol mandate levels than those proposed by EPA.

Our model shows that if existing E85 stations could sell as much E85 as demanded by consumers, and if E85 were priced at fuel-cost parity with E10, then ethanol consumption in E85 would be 1.65 billion gallons. If E85 were priced to generate a 20 percent reduction in fuel costs to consumers, then ethanol consumption would increase by 3.6 billion gallons per year. These calculations assume no growth in the number of flex vehicles above the level that existed on January 1, 2013. However, it is not realistic to assume that existing E85 stations could sell unlimited amounts of the fuel. Imposing an upper limit on monthly E85 sales of 45,000 gallons per station reduces ethanol-in-E85 consumption levels to 700 million gallons per year at parity prices, and 900 million gallons per year at a price that results in a 20 percent reduction in fuel costs. The large gap between how much E85 would be demanded by consumers and what can realistically be sold by existing stations shows that both price and the number of gasoline stations selling E85 constrain consumption.

We show the impact of adding E85 sales outlets in urban areas where flex vehicles are concentrated by calculating the different combinations of new sales outlets and E85 retail prices needed to achieve an ethanol consumption target beyond E10. An additional ethanol consumption target of 800 million gallons could be achieved with an E85 retail price of \$2.32 per gallon and no new stations. If 500 new stations were added, then the required retail price increases to \$2.71 per gallon. These results demonstrate that meeting a 14.4 billion gallon ethanol mandate is feasible in 2014 with no new stations, modestly lower E85 prices, and judicious use of available carryover RINs (Renewable Identification Numbers).

Meeting a two billion gallon increase in consumption would require installing at least 3,000 new stations. At a cost of \$130,000 per station, this would require a one-time investment of \$390 million, or about 20 cents per gallon of increased ethanol consumption in one year. With 3,000 additional stations, the retail price of E85 would have to be discounted to \$2.10 per gallon to generate two billion gallons of additional ethanol consumption. With a total of 3,500 new stations, the required E85 retail price increases to \$2.60 per gallon.

The large impact that adding new stations has on the retail price of E85 given a level of E85 sales gives EPA a powerful tool to incentivize investment in new stations that can

facilitate meeting expanded ethanol consumption targets. Any gap that arises between the wholesale price of ethanol needed to support a lower retail E85 price and the cost of producing and transporting ethanol would be closed by the price of RINs. RIN prices also indicate the cost that owners of oil refineries bear to meet biofuel mandates. Thus, there exists an inverse relationship between the cost of compliance with mandates and the number of new E85 stations. This means that owners of oil refineries who bear the costs of complying with mandates can reduce their compliance costs by investing in new E85 stations.

If EPA were to set the 2014 ethanol mandate at 14.4 billion gallons and the mandate was met by 13 billion gallons of ethanol in E10, 800 million gallons of ethanol in E85, and 600 million banked RINs, then the RIN price that would cover the gap between the required \$2.32 per gallon price of E85 and the cost of producing and transporting ethanol would be 69 cents per RIN. With 500 additional stations, the RIN price would drop to 18 cents. This drop in RIN price represents more than a \$7 billion drop in the total value of RINs that would be used for compliance in 2014. In this scenario, the cost of adding the additional stations would be \$65 million. This dramatic decrease in the total cost of RINs from adding new E85 stations is what gives EPA the tool they need to incentivize the investments that would facilitate expanded ethanol mandates.

EPA's proposed rule would reduce mandated volumes of biofuels in part, because of "supply concerns associated with the blendwall." We demonstrate in this paper that the important supply concern associated with the E10 blendwall pertains to the supply of stations that sell E85, not the supply of the biofuel. The lack of stations that sell the fuel results in a lack of demand for ethanol, not a lack of supply. EPA's justification for reducing ethanol mandates means that mandates will not be increased beyond E10 levels until the number of stations that sell E85 increases sufficiently. Our results demonstrate that the number of stations that sell E85 will not increase until EPA sets ethanol mandates beyond E10 levels. If increased mandates wait for the stations to be built, mandates will never increase.

Our results showing that 800 million gallons of ethanol can be consumed as E85 in 2014, even with no additional investment in E85 stations can provide one way out of this policy dilemma. Combining this additional consumption of ethanol in E85 with consumption of ethanol in E10 and available banked RINs would facilitate meeting a 14.4 billion gallon mandate in 2014. Adopting a 14.4 billion gallon ethanol mandate would send a clear signal that EPA is not locked into keeping ethanol mandates below E10 levels. It would also increase RIN prices enough to incentivize investments in new E85 stations, which would give EPA the freedom to move the ethanol mandate to 15 billion gallons in 2015. Our results show that it will take at least 3,000 additional stations selling E85 to achieve a 15 billion gallon mandate without use of carryover RINs. If all 3,000 stations needed an additional tank for E85, then it will involve a one-time investment cost of approximately \$390 million, or about 20 cents for each gallon of ethanol sold in E85. Because this investment cost is far below what compliance costs would be without the investment, owners of oil refineries would have a strong incentive to make the investment.

Introduction

The proposed decision by EPA to reduce biofuel mandates is predicated in part on a finding that consumption of ethanol is largely limited to the amount that can be consumed in E10—commonly referred to as the E10 blendwall. The Energy Information Agency (EIA) reported that in 2013 total motor fuel consumption in the United States would be 134.4 billion gallons, and projected consumption of 134 billion gallons in 2014.¹ EPA thus concluded that consumption of ethanol in 2014 is limited to about 13 billion gallons, which explains why EPA proposed biofuel mandates in 2014 that included 13 billion gallons of ethanol.²

EPA recognizes in its proposed rule that some ethanol can be consumed in higher ethanol blends, such as E85. EPA asks for help in identifying data that can be used to estimate more precisely how much ethanol can be consumed in higher blends. Data on historical consumption of E85 in the United States published by EIA shows E85 consumption of 190 million gallons in 2011. One reason for this low level of consumption is that only owners of flex-fuel vehicles can use the fuel. Although there were approximately 15 million flex vehicles on the road in 2013, most are located in major metropolitan areas without easy access to stations that sell E85. However, most flex vehicle owners did not fill up with E85 even if they lived close to an E85 station because its price was too high. Because ethanol has a lower energy content than gasoline, the price of E85 must be at least 20 percent lower than the price of E10 to equalize fuel cost per mile traveled.

One reason the price of E85 has been high is that the value of ethanol in an E10 blend does not necessarily reflect its lower energy content because ethanol's high-octane content offers oil refiners and blenders additional value. It is common sense that ethanol will flow to its highest-value use until that use is saturated, and ethanol in E10 is of higher value than ethanol in E85. Another reason for high E85 prices is that the cost of producing ethanol has been higher than the value of ethanol as a straight substitute for gasoline based on energy value. High corn prices from 2010 until the fall of 2013 made it difficult for ethanol to compete with gasoline. The third reason for high E85 prices is that biofuel mandates have been met by levels of ethanol that could be consumed in E10, or by using "banked" ethanol consumption credits (RINs). In 2013 for example, the mandate level that could be met with corn ethanol was set at 13.8 billion gallons. This level will be met with less than 13 billion gallons of ethanol in E10 with the balance coming from banked credits. To date there has never been a need to price E85 at a level that would increase ethanol consumption beyond 13 billion gallons.

The mandate that can be met with corn ethanol was scheduled to increase to 14.4 billion gallons in 2014 and to 15 billion gallons in 2015. The current number of banked ethanol credits is no longer sufficient to allow these mandate levels to be met if ethanol consumption is limited to 13 billion gallons in E10. Thus, the 14.4 billion gallon mandate in 2014 would have created an economic reason for pricing E85 low enough to increase sales. Increased sales of E85 combined with E10 ethanol consumption and some use of banked ethanol consumption credits would have been the least-cost way of meeting the 14.4 billion gallon ethanol mandate in 2014.

¹ See US EIA Short Term Energy Outlook, December 10, 2013.

² EPA's proposed volumes could result in slightly higher volumes of ethanol being consumed if imported sugar cane ethanol outcompetes biodiesel for the small amount of the proposed advanced mandate that is not made up by biomass-based diesel.

However, under the EPA proposal, the ethanol mandate in 2014 would be reduced to 13 billion gallons—a level that can easily be met with E10. Thus, there would be no policy incentive to increase consumption of E85 under the proposed rule. Our purpose in writing this paper is to examine EPA’s assumption that the ability to expand ethanol consumption is so limited that ethanol mandates had to be reduced to the E10 blendwall. We estimate the feasibility and cost of meeting ethanol mandates of 14.4 billion gallons in 2014 and 15 billion gallons in 2015 through a combination of consumption of E10 and E85, and a complete drawdown of banked ethanol consumption credits.

How Much E85 Can Be Consumed?

In the summer of 2013 we built a model of E85 demand in the United States.³ The demand model accounts for the distance that owners of flex fuel vehicles must drive to find a station that sells E85 and imposes an additional cost of filling up with E85 based on this distance. The model also accounts for differences in the willingness among flex vehicle owners to buy E85 for different price discounts and premiums relative to the price of E10. Data from Brazil were used to estimate these differences. The model assumes that consumers choose whether to use E85 or E10 based on the total cost per mile traveled for the two fuels and based on different non-cost preferences for the two fuels. Thus, the price of E10 is a critical factor in determining the position of the demand curve for E85. Figure 1 shows two demand curves for E85 with existing E85 stations and flex vehicles and fixing the E10 retail price at \$3.43 per gallon.⁴ The number of flex vehicles is held constant at the level that existed on January 1, 2013.

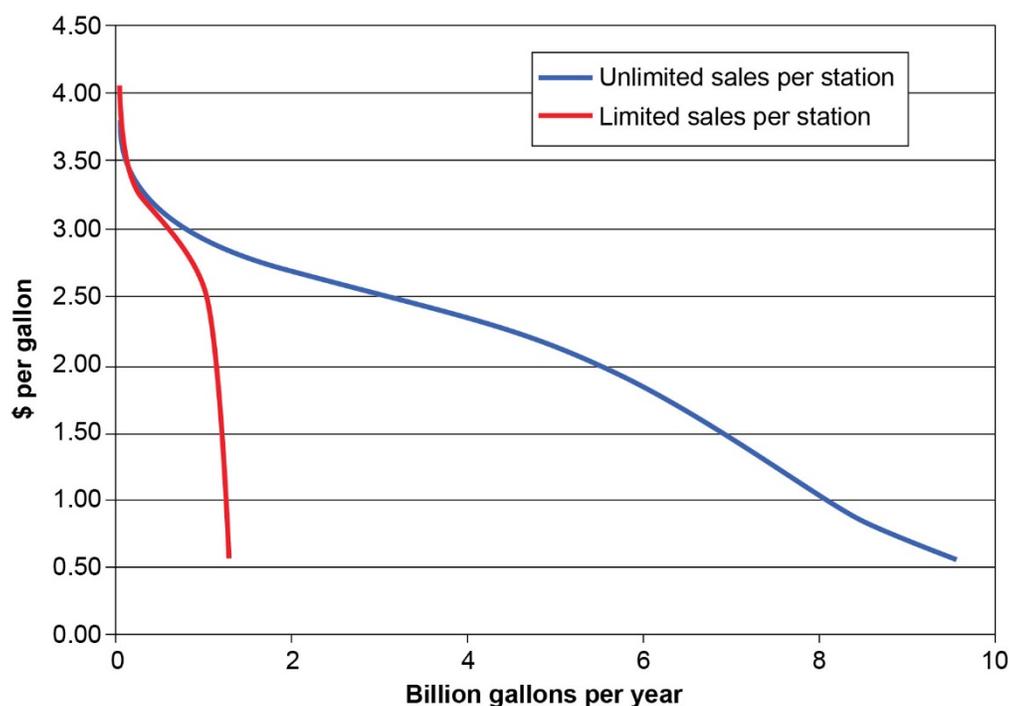


Figure 1. Demand curves for E85 fixing E10 price at \$3.43 per gallon

³ Babcock, B.A., and S. Pouliot. “Price It and They Will Buy.” 13-PB 11. Center for Agricultural and Rural Development, Iowa State University. August 2013. This model has recently been revised in response to a request for a revision to a peer-reviewed journal. The revised model was used to generate the results in this paper. Results from the original model would have been very close to those presented here.

⁴ In its December, 2013, Short Term Energy Outlook, the US EIA projects that the average US price for regular gasoline in 2014 will be \$3.43 per gallon.

The right demand curve in Figure 1 shows the quantity of E85 that would be consumed for different price levels if existing E85 stations could each sell an unlimited amount of E85. At low E85 prices, many stations would have to sell upwards of a million gallons of E85 per month to achieve the consumption levels shown in this demand curve. However, this is an unreasonable assumption because the average amount of fuel sold per station in the United States is about 100,000 gallons per month. The left demand curve assumes that no station can sell more than 45,000 gallons of E85 per month. This is a rather rigid limit, but the most E85 that any station has sold in a month, was about 50,000 gallons, sold in May of 2013 by a station in Minnesota. The distance between these two demand curves shows that the number of stations selling E85 limits consumption more than the number of flex vehicles, because the right demand curve could be achieved by simply locating more E85 stations in the same locations as existing stations. Demand could be increased even more if stations were located more strategically to minimize the distance that owners of flex vehicles had to drive to purchase E85.

Figure 1 shows that E85 sales could reach almost 10 billion gallons per year if there were enough stations selling the fuel, and if the price of E85 was heavily discounted. With a 45,000 gallon monthly sales limit, total consumption of E85 cannot exceed 1.25 billion gallons per year no matter how large a discount is given to the fuel.

Biofuel mandates are expressed in terms of gallons of ethanol consumption per year, not gallons of E85 per year. Figure 2 converts quantities of E85 into quantities of ethanol and converts the price of E85 into the ratio of fuel cost per mile traveled using E85 compared to E10. The fuel-cost parity price of E85 is 77.5 percent of the price of E10 when E85 contains 75 percent ethanol. Thus, the parity price of E85 is \$2.66 per gallon when the price of E10 is \$3.43 per gallon. What Figure 2 indicates is that if E85 were

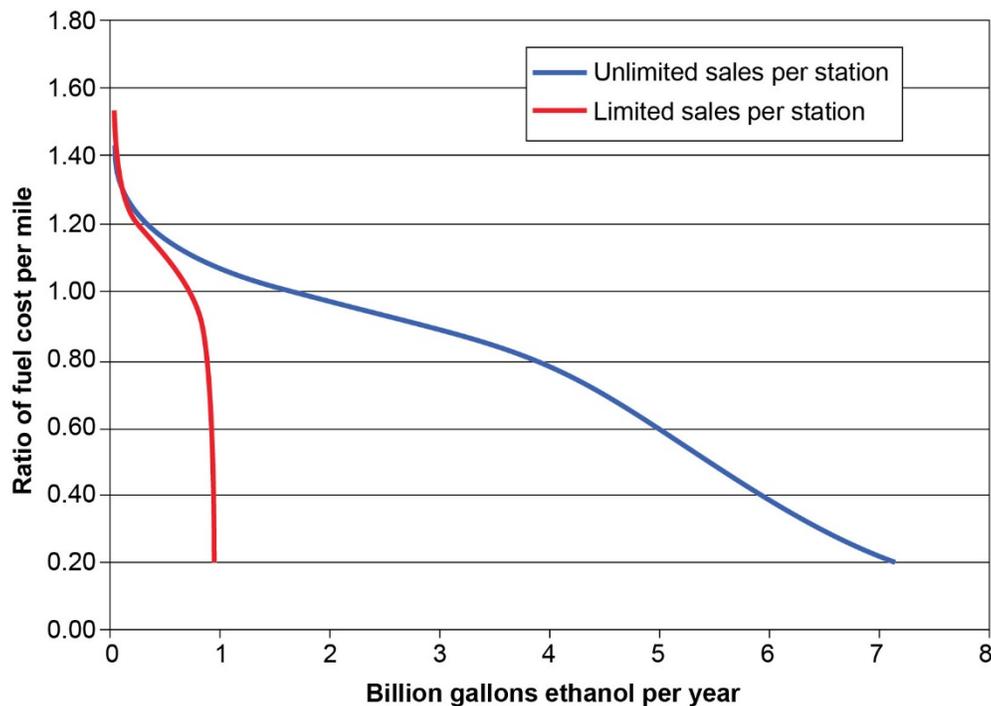


Figure 2. Ethanol consumption levels for different fuel cost ratios

priced at parity with E10 at all stations for an entire year, then about 700 million gallons of ethanol would be consumed in E85 with the 45,000 gallons per month sales limit. Parity pricing would result in about 1.65 billion gallons in ethanol sales without the sales limit. Pricing E85 so that it generates a 20 percent savings in fuel cost would result in 900 million gallons of increased ethanol consumption with the sales constraint in place, and more than 3.6 billion gallons without the sales constraint. These results indicate that the two keys to meeting expanded ethanol consumption levels through E85 are increasing the number of stations that sell the fuel and pricing the fuel at levels where it makes sense for owners of flex vehicles to buy it instead of E10. The next section explores how strategically locating additional stations that sell E85 shifts the demand curves shown in Figure 2.

Impact on Demand for E85 with New Stations

The wide gap between the two demand curves in Figure 2 is an indicator of unmet demand for E85. This unmet demand increases rapidly as the price of E85 falls below parity. This result makes intuitive sense because owners of flex vehicles will want to buy E85 when it saves them money, but they will not buy the fuel if it is not available.

Many E85 stations are at their constrained sales level of 45,000 gallons per month when the price of E85 is at parity with E10. These stations have no incentive to charge any less for the fuel even if the E85 wholesale price drops, because they cannot sell any more. Instead, these stations will simply increase their markup and profits. However, profits to an existing station are a signal to competing stations to start selling the fuel. Areas that have the most unmet demand are the locations where it makes the most sense to locate new E85 stations.

It is straightforward to calculate unmet demand because our demand model calculates the number of flex vehicles in each US zip code that do and do not fill up with E85 for any given price. We created a computer program to rank each zip code according to the number of flex vehicles that do not use E85 at a given price. Those zip codes with the greatest number of such vehicles receive the first E85 stations to be added, and lower-ranked zip codes receive E85 stations in turn. So if we want to estimate the impact of installing an additional 2,500 stations, we first satisfy unmet demand in the highest ranked zip codes, and then keep allocating additional stations to lower ranked zip codes until 2,500 stations are installed. We estimated the impact on demand from adding new stations in increments of 500 stations up to 7,500 stations. The results of adding 500, 1,500, 2,500, and 3,500 stations are shown in Figure 3.⁵

The impact on the quantity of ethanol consumed from adding stations when the price of E85 is priced above parity is small because most flex vehicle owners do not want to purchase E85 when it costs more than E10. However, the impact of adding stations is substantial when E85 is priced at parity or below. For example, adding 500 stations would increase the amount of ethanol consumed in E85 from to 700 to almost 900 million gallons. Adding another 1,000 stations would increase ethanol consumption to 1.26 billion gallons. If 3,500 stations were added, and if ethanol were priced at parity, then 1.9 billion gallons of ethanol would be consumed in E85. This result is notable because this quantity of ethanol almost equals the additional quantity that would need to be consumed as E85 to meet a 15 billion gallon mandate in 2015. As shown in Figure 3 the two ways to increase ethanol consumption in E85 are to expand the number of

⁵ If E85 were as widely available as E10, the consumption of E85 at fuel cost parity with E10 would be approximately six billion gallons.

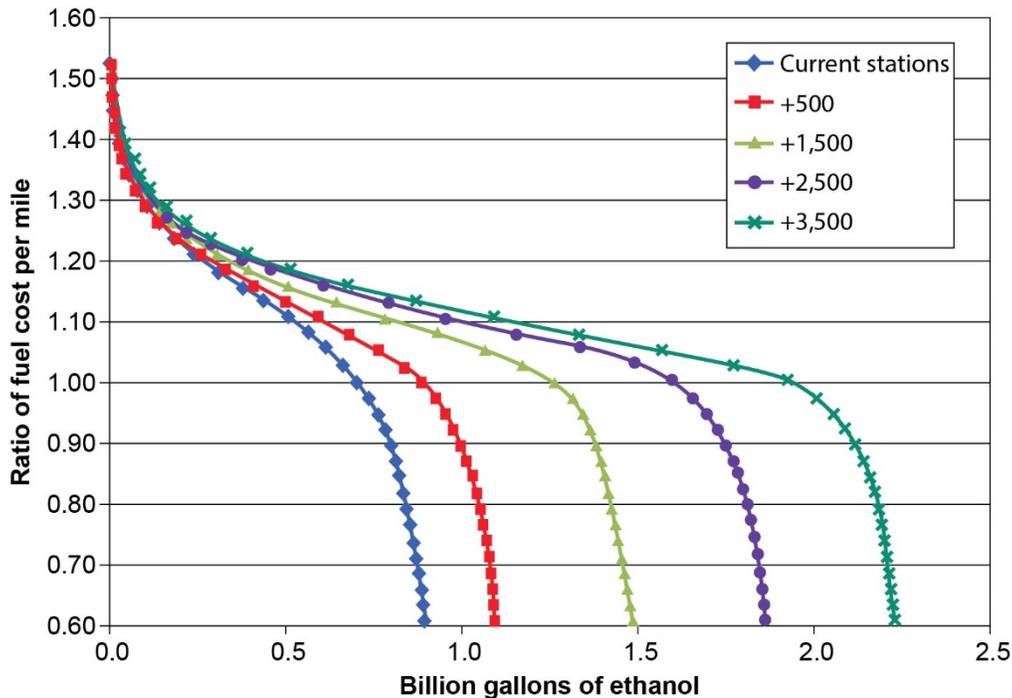


Figure 3. Impact on ethanol demand from adding E85 stations

stations that sell the fuel and to lower its price. It is important to consider the effects of E85 price on consumption levels because EPA has more control over the price of E85 than it does over the number of stations. This influence over price is what gives EPA a powerful policy tool to incentivize the installation of new stations.

How the Price of E85 Reflects Mandate Levels

Compliance with biofuel mandates is achieved by requiring gasoline and diesel producers and importers to acquire and give to EPA enough RINs to meet their obligations. RINs are produced with biofuels and can be acquired either by buying the biofuel or by entering the market for RINs and buying them from a seller. Sellers of RINs are primarily blenders who buy biofuels and the associated RINs. Blenders who have no obligation to meet biofuels mandates have no need for the RINs, so they sell their RINs to owners of oil refineries who face the obligation but do not buy biofuel directly. The price of RINs reflects the incremental financial burden of meeting a biofuel mandate. If a mandate is not a burden to meet then the price of RINs will be low. If a mandate is set at a level that is difficult to achieve then RIN prices will be high.⁶

The economic theory of RIN prices is that they reflect the gap between the incremental market value of a biofuel to a buyer and the cost of producing an incremental amount of the same biofuel. Because production costs increase as more biofuels are produced and because the value of biofuels decreases as more are consumed, the cost-value gap increases with mandate levels. A difficult-to-achieve mandate is reflected in a wide cost-value gap, which implies a high RIN price.

⁶ For more details about how compliance costs influence the market price of RINs see Babcock, B.A. "RFS Compliance Costs and Incentives to Invest in Ethanol Infrastructure." 13-PB 13. Center for Agricultural and Rural Development, Iowa State University, September 2013. and Babcock, B.A. and S. Pouliot "RFS Compliance: Death Spiral or Investment in E85." 13-PB 16. Center for Agricultural and Rural Development, Iowa State University.

An example will illustrate how RIN prices reflect this gap: Suppose that EPA decides to impose a 13.8 billion gallon ethanol mandate. To meet this mandate will require 13 billion gallons of ethanol consumed as E10 and 800 million gallons consumed as E85. To induce owners of flex fuel vehicles to buy 800 million gallons of ethanol will require pricing E85 at a level that generates a 10 percent savings in fuel cost per mile assuming that no new E85 stations are built, as shown in Figure 3. With a \$3.43 per gallon price of E10, this requires an E85 retail price of \$2.39 per gallon.

For simplicity, suppose that the markup between wholesale and retail fuel prices is a constant 75 cents per gallon. This means that the wholesale price of E85 must be \$1.64 per gallon. If we make the further assumption that the wholesale price equals the weighted average of wholesale ethanol and gasoline prices, and use a \$2.68 per gallon wholesale price of gasoline, then this implies that the wholesale ethanol price must be \$1.29 per gallon. That is, if the wholesale price of ethanol is \$1.29 per gallon and the wholesale price of gasoline is \$2.68 per gallon, then the wholesale price of E85 will be \$1.64 per gallon if E85 contains 75 percent ethanol. In other words, the only way to induce owners of flex vehicles to buy enough E85 to increase sales of ethanol by 800 million gallons is with a wholesale ethanol price of \$1.29 per gallon.

A problem arises if the incremental cost of producing 13.8 billion gallons is greater than \$1.29 per gallon. Suppose that the cost of producing and transporting a gallon of ethanol to a blender is \$1.80 per gallon. This means that unless the ethanol plant is paid at least \$1.80 per gallon for ethanol (and the plant pays for transporting the ethanol to the blender) it will not arrive at the blender. With an ethanol value of only \$1.29 per gallon when blended in E85 the blender cannot afford to pay \$1.80 per gallon. But the blender can afford to pay \$1.29 per gallon for the ethanol and another \$0.51 per gallon for the RIN that comes along with the ethanol. The ethanol plant sells both the RIN and the gallon. If the RIN price is \$0.51 per gallon and the ethanol price is \$1.29 per gallon, together they cover the cost of producing and transporting the ethanol to the blender. It is in this way that the RIN price closes the gap between the cost of producing ethanol and the value that ethanol brings on the market.

Now suppose that EPA is concerned that a RIN price of \$0.51 per gallon is too high because owners of oil refineries threaten to pass the cost of these RINs on to consumers through higher gasoline prices.⁷ So EPA decides to reduce the ethanol mandate to 13.65 billion gallons. Now only 650 million gallons of ethanol need to be consumed in E85 to meet the mandate. From Figure 3 we can calculate that the retail price of E85 that will result in 650 million gallons of consumption is \$2.75 per gallon. This retail price requires a wholesale ethanol price of \$1.77 per gallon which is only three cents below the \$1.80 cost of production and transportation. The RIN price now needed to ensure that the mandate is met is only three cents per gallon. By lowering the mandate from 750 million gallons to 650 million gallons EPA lowers the RIN price by 48 cents per gallon and increases the E85 retail price by 36 cents per gallon.

Conversely, if EPA were to decide that a 13.8 billion gallon mandate was too modest of a goal and instead set the mandate at 13.9 billion gallons, the required E85 retail price would be \$1.54 per gallon. This implies a wholesale ethanol price of only 16 cents per

⁷ For a discussion of why it would be difficult for oil companies to increase prices to consumers see Babcock, B.A. and S. Pouliot "RFS Compliance: Death Spiral or Investment in E85." 13-PB 16. Center for Agricultural and Rural Development, Iowa State University, November, 2013.

gallon, which in turn implies a RIN price of \$1.64 per gallon. Although this last example is quite extreme, it nicely illustrates that by controlling the level of the mandate EPA controls both the price of RINs and the price of E85. This control over RIN prices and E85 prices is what gives EPA the ability to create incentives to meet much higher mandates than could currently be met given current infrastructure. Before demonstrating how, we now turn to identifying feasible compliance paths for increased ethanol mandates in 2014 and 2015.

Feasible Compliance Paths for 2014 and 2015

A combination of banked ethanol credits and new ethanol blending would have been used for compliance if EPA had proposed to maintain the mandates that can be met by corn ethanol for 2014 and 2015 at 14.4 and 15.0 billion gallons, respectively. Paulson recently calculated that there will be at most one billion carryover ethanol RINs that could be used for compliance.⁸ However, it is not possible to say exactly how many of these RINs will actually be available to meet 2014 mandates. Suppose that 800 million will be available. If 600 million are used for compliance in 2014 and 200 million in 2015, then to meet a 14.4 billion gallon mandate in 2014 will require physical blending of 13.8 billion gallons of ethanol. To meet a 15 billion gallon mandate in 2015 will require 14.8 billion gallons of physical blending. After 2015 there will be no more carryover RINs available, so 15 billion gallons of ethanol would need to be consumed in 2016.⁹ Subtracting 13 billion gallons of E10 from these quantities would mean that as E85 800 million gallons of ethanol would need to be consumed in 2014, 1.8 billion gallons would need to be consumed in 2015, and 2 billion gallons would need to be consumed in 2016.

Recall that that the two ways to increase ethanol consumption through E85 are to lower the price of E85 or to install new E85 stations, or a combination of these two options. The demand curves in Figure 3 can be used to calculate the combinations of E85 prices and new E85 stations that result in the same level of consumption. These combinations are all feasible ways of achieving a given target level of consumption. The results are illustrated in Figure 4 for consumption ranging from 800 million to 2 billion gallons of ethanol consumed in E85, which is in excess of consumption in E10 and carried over RINs.

A target level of consumption of ethanol in E85 of 800 million gallons could be met with no new stations and a pump price of \$2.32 per gallon. If 500 new E85 stations were strategically located, then 800 million gallons of consumption could be achieved with a much higher pump price of \$2.71 per gallon. Given sales of 800 million gallons of ethanol in E85, the addition of 500 new stations provides more than \$400 million in value that can be captured from the sales of E85. These results indicate that it is feasible to meet a 14.4 billion gallon ethanol mandate in 2014 even without any new investments in stations. Adding an additional 500 stations in 2014 would make the target easier to achieve, but the assumption by EPA that a 14.4 billion gallon ethanol mandate in 2014 was not feasible is not correct. A combination of discounted E85 and the judicious use of carryover RINs would have allowed for compliance.¹⁰

⁸ Paulson's calculations are available at <http://farmdocdaily.illinois.edu/2013/12/rin-update-2014-carry-in-epa-rulemaking.html>

⁹ RINs can be carried over only one year, but owners of RINs can carry over RINs indefinitely by using their oldest RINs first in any given year.

¹⁰ According to a Reuter's report written by Michael Hirtzer, in the summer of 2013 Steve Wall of Protec Fuel was on the verge of selling enough new E85 pumps to two oil refineries to increase the number of stations that sell E85 by 450. This one sale would have accomplished a dramatic decrease in RIN prices. The article is

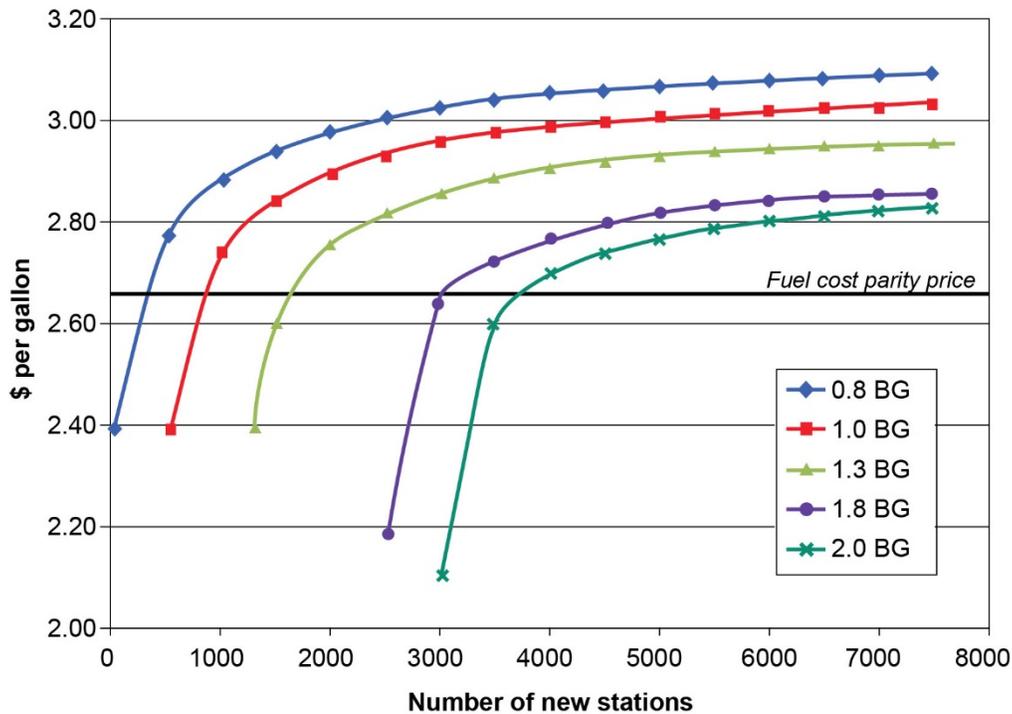


Figure 4. Feasible compliance paths for alternative ethanol volumes

It is not possible to achieve an additional 1.8 billion gallons of ethanol consumption in 2015 without new stations. Figure 4 shows that at least 2,500 new E85 stations would be needed to achieve this level of consumption; and even with this large number of stations the price of E85 would have to be discounted to \$2.18 per gallon. If 500 stations were installed in 2014 and 2,500 more installed in 2015, then the price of E85 would only have to be discounted to \$2.64 per gallon to achieve 1.8 billion gallons of consumption. If EPA were to conclude that investment in stations could not be achieved this rapidly then it could opt for a lower target for 2015. Two intermediate curves are provided in Figure 4 to facilitate calculation of the retail E85 prices and the number of new stations that sell E85 that would combine to achieve ethanol consumption levels in E85 of 1 and 1.3 billion gallons.

To achieve the 15 billion gallon level of consumption would require a minimum of 3,000 new E85 stations strategically located; and even with 3,000 new stations the price of E85 would have to be discounted to \$2.10 per gallon. Adding an additional 500 stations on top of the 3,000 stations would significantly reduce the required E85 discount. This tradeoff between the required price of E85 and the number of new stations selling the fuel is the key to understanding why EPA decisions about mandate levels are so important in determining whether investments in new stations actually occurs. We turn to this issue in the next section.

The results in this section demonstrate that higher ethanol mandates supported by E10 consumption are feasible to achieve. The 14.4 billion gallon mandate level in 2014 is feasible to achieve even if no new E85 stations are added. Adding stations would lower

available at <http://www.reuters.com/article/2013/11/27/us-usa-ethanol-e85-analysis-idUSBRE9AQ1AU20131127>.

the cost of meeting the 14.4 billion gallon mandate and, more importantly, would allow EPA to increase mandates by even more in the future.

How EPA Decisions Will Determine Investments in New E85 Stations

Compliance with mandates that push ethanol consumption in excess of 13 billion gallons would be accomplished through a combination of lower E85 prices and investment in new E85 stations. Currently there are about 2,500 fuel stations that dispense E85, which is about 2 percent of all US fuel stations. Figure 4 shows that increasing the number of new E85 stations would decrease the discount on the price of E85 needed to achieve consumption of a given amount of ethanol in E85. In addition, for any given number of new E85 stations, discounts on E85 reflect the difficulty in selling larger amounts of ethanol and this in turn causes higher RIN prices. This means that there is an inverse relationship between RIN prices and the number of E85 stations. Because RIN prices measure the incremental cost of compliance with mandates there is also an inverse relationship between the cost of compliance with mandates and the number of new E85 stations. This means that owners of oil refineries who bear the costs of complying with mandates can reduce their compliance costs by investing in new E85 stations. Of course compliance costs would be reduced if any private or public entity increased the number of new E85 stations. Oil refineries just have the largest financial incentive when faced with high RIN prices.

To quantify the tradeoff between RIN prices and the number of new stations requires making some assumptions about the cost of producing ethanol. Table 1 shows the assumptions made here. The minimum price that is needed to deliver ethanol to a blending station given the assumptions in Table 1 is \$1.85 per gallon. Ethanol will not be produced and delivered unless blenders pay at least \$1.85 per gallon for delivered ethanol. The last assumption that we need before calculating RIN prices is whether retailers will need an additional per-gallon incentive to sell E85 beyond what they receive selling E10. Selling gasoline is a low margin business so adding some additional margin to E85 would increase retailers' willingness to sell the fuel. To ensure that we do not understate required RIN prices we assume that an additional markup of 10 cents per gallon is added to the 75 cent per gallon markup for E10. This additional markup increases RIN prices by 13 cents per gallon.

Table 1. Assumptions about costs of producing ethanol

Prices	
Corn (\$/bu)	4.00
Natural Gas (\$/mmBTU)	5.60
Dry Distillers Grains (\$/ton)	143
Costs and Byproduct Value(\$/gal)	
Corn	1.43
Natural Gas	0.15
Other Variable	0.30
Transportation	0.40
Total Variable Cost	2.07
Value of Distillers Grains	0.43
Net Cost	1.85

Figure 5 shows the combinations of RIN prices and new E85 stations that are needed to meet alternative ethanol-in-E85 consumption targets. A RIN price of 69 cents per gallon would cover the gap between the cost of producing and transporting ethanol and the wholesale price of E85 that is needed to induce 800 million gallons of beyond-E10 ethanol consumption if no new stations were added. The RIN price would drop to 18 cents per gallon at the same consumption level if 500 new stations were added. If 1.8 billion gallons of additional consumption are needed in 2015 then at least 2,500 additional E85 stations need to be installed. The RIN price with these 2,500 stations would be 97 cents per gallon. If instead 3,000 stations were installed, then the RIN price would drop to 39 cents per gallon.

The dramatic impact that additional E85 stations can have on RIN prices creates a strong incentive for owners of oil refineries to invest in stations to lower their compliance costs. For example, Delta Air Lines owns an oil refinery in Pennsylvania, but does not blend ethanol so it needs to buy RINs to comply with the biofuel volume mandates in the Renewable Fuel Standard (RFS). Because Delta does not sell blended gasoline, it gets no benefit from inexpensive ethanol that offsets high RIN prices, so high RIN prices are a direct additional cost to Delta.

If Delta produces one billion gallons of gasoline per year, it would need to purchase approximately 107 million RINs to be in compliance with an ethanol mandate of 14.4 billion gallons per year in 2014. At a RIN price of 69 cents per gallon, Delta faces compliance costs of \$74 million per year. Delta's compliance costs would be reduced by

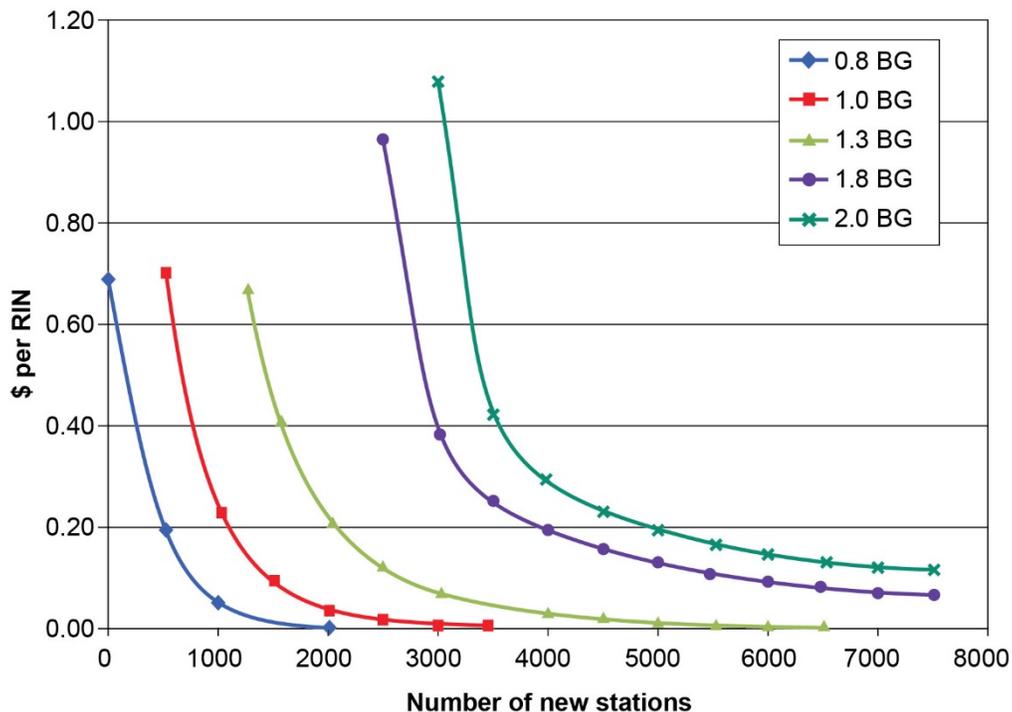


Figure 5. Tradeoff curves between RIN prices and new E85 stations to meet ethanol consumption levels

about \$55 million per year if 500 additional E85 stations were strategically located.¹¹ EPA (2010) estimated that installing a tank and pump to facilitate sales of E85 involves construction costs of \$130,000 per station.¹² The cost of installing 500 stations all with

new tanks then is \$65 million, which just about balances the one-year reduction in Delta's compliance costs even if Delta gave away any other return on this investment. The upfront investment cost of the stations would also continue to generate savings in compliance costs in the future.

Of course, Delta would get the same benefit if Exxon or any other entity installed the additional 500 E85 stations so it is not clear why Delta would actually make the full investment. However, every other oil refinery would face the same incentive as Delta, so all would have a strong incentive to increase E85 sales to reduce compliance costs.¹³ As shown in Figure 5, RIN prices could be reduced to less than one cent if 1,500 new E85 stations were strategically installed. This number of stations would reduce compliance costs to Delta and all other refineries to near zero in 2014. This example demonstrates that a decision by EPA to adopt a 14.4 billion gallon ethanol mandate in 2014 would create a strong incentive to invest in new E85 stations to simply reduce 2014 compliance costs.

The incentive to install new E85 stations would be even stronger if EPA were to announce mandates of 14.4 billion gallons in 2014 and 15 billion gallons in 2015. Even though it is technically feasible to meet a 14.4 billion gallon mandate in 2014 with no new investment, the cost of meeting the mandate would fall dramatically by investing in 1,500 stations. Figure 5 shows that a total of at least 3,000 stations would be needed in 2015 to make it feasible to meet the 15 billion gallon mandate. It would be much easier for oil refineries to justify the first 1,500 stations to lower their compliance costs if they know that they will need 1,500 more stations in 2015.

Figure 5 shows that there are initially large, but sharply diminishing, reductions in RIN prices from investing in new E85 stations. Given these diminishing returns to investing in E85 stations, a 15 billion gallon mandate for 2015 and beyond would likely induce enough investment to lower RIN prices to about 20 cents per gallon, which would require about 5,000 new E85 stations. If cellulosic ethanol production ramps up in 2016 and beyond, additional incentives to install new stations to facilitate consumption of more ethanol would likely materialize.

The analysis presented here is limited to consideration of feasible compliance paths using E85 to increase ethanol consumption. Compliance could also be achieved using E15, which has been approved by EPA for model year 2001 and later light duty vehicles. High RIN prices also create an incentive to install E15 pumps in existing stations. The exact combination of E85 and E15 that would be used for compliance would depend on which minimizes compliance costs. The cost of installing E15 sales capability in a station is lower than installing E85 capability, but E85 contains far more ethanol than E15 so fewer E85 pumps would need to be installed.

¹¹ It would actually be a tank and pump that would be installed at an existing station that would allow E85 to be sold.

¹² US Environmental Protection Agency, Assessment and Standards Division, Office of Transportation and Air Quality. 2010. "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis." EPA-420-R-10-006.

¹³ Oil refineries have an even stronger incentive to lobby against the need to sell E85 by convincing the EPA to lower mandates to below E10 blendwall levels.

Policy Implications

Our results show that increasing consumption of ethanol beyond E10 levels can be accomplished either by reducing the price of E85 or by increasing the number of stations that sell the fuel. For any given consumption target there is an inverse relationship between how much the price of E85 must be reduced and the number of stations that sell the fuel. The RIN trading system that EPA uses to enforce biofuel mandates is the mechanism that would facilitate the required price reductions in E85. The greater the reduction in E85 price that is required to induce consumers to use the fuel, the greater the RIN price. Higher RIN prices imply higher compliance costs for owners of oil refineries. Thus, high RIN prices create an incentive for these owners to lower their compliance costs by increasing the number of stations that sell E85. An increase in the number of E85 stations would increase the demand for E85, increase the price of E85, lower RIN prices, and thus lower compliance costs.

The key point is that creation of sufficient demand to meet ethanol blending targets that exceed E10 levels is contingent on EPA setting mandates sufficiently high to incentivize the investments in fueling infrastructure that allow the targets to be met. The more ambitious the blending target, the higher compliance costs will be, and the greater the incentive to invest in fueling infrastructure that will lower compliance costs and facilitate meeting the ambitious target.

EPA's proposed rule would reduce mandated volumes of biofuel in part because of "supply concerns associated with the blendwall."¹⁴ As demonstrated here the important supply concern associated with the E10 blendwall pertains to the supply of stations that sell E85, not the supply of the biofuel. The lack of stations that sell the fuel results in a lack of demand for ethanol, not a lack of supply. EPA's justification for reducing ethanol mandates means that mandates will not be increased beyond E10 levels until the number of stations that sell E85 increase sufficiently. Our results demonstrate that the number of stations that sell E85 will not increase until EPA sets ethanol mandates beyond E10 levels. If increased mandates need to wait for the stations to be built, mandates will never increase.

One way out of this policy dilemma is suggested by our result showing that 800 million gallons of ethanol can be consumed as E85 in 2014 even with no additional investment in stations that sell the fuel. Combining this additional consumption of ethanol in E85 with consumption of ethanol in E10 and with available banked RINs would facilitate meeting a 14.4 billion gallon mandate in 2014. This level of mandate would be equal to what was expected for 2014, not accounting for any volumes of cellulosic or other advanced ethanol. Adopting a 14.4 billion gallon ethanol mandate would send a clear signal that EPA is not locked into keeping ethanol mandates below E10 levels. It would also increase RIN prices enough to incentivize investments in new E85 stations, which would give EPA the freedom to move the ethanol mandate to 15 billion gallons in 2015. Our results show that it will take at least 3,000 additional stations selling E85 to achieve a 15 billion gallon mandate without use of carryover RINs. If all these stations needed an additional tank for E85, then this involve a one-time investment cost approximately \$390 million, or about 20 cents for each gallon of ethanol sold in E85.

The implications for agriculture and the biofuel industry of adopting EPA's proposed rule are potentially far reaching because ethanol consumption growth would be halted.

¹⁴ P. 71737 Federal Register Vol. 79 No. 230/Friday, November 29, 2013, Proposed Rules.

Any growth in the domestic consumption of ethanol from cellulosic materials will come only with a reduction in the consumption of ethanol from corn. Opponents of corn ethanol will certainly applaud this implication. However, the RFS originally envisioned that growth in consumption of cellulosic ethanol would be on top of a fixed level of consumption of corn ethanol. The EPA proposed rule means that cellulosic ethanol producers will compete with corn ethanol producers for a fixed ethanol market rather than an expanding market. This is a fundamental change in how the RFS was originally intended to work, and would change the political dynamic of how different ethanol groups work together moving forward. Certainly this change in policy, if accompanied by a recommitment to future support of cellulosic biofuels, boosts the prospects for producers of drop-in biofuels. However, it would be difficult to interpret EPA's proposed fundamental shift in policy as anything except a reduction in overall support for biofuels, however nuanced one might want to interpret the intent of the proposed rule.