Breaking the Blendwall:
Meeting the RFS through expanded E85 consumption

Joseph I. Greene
Christopher L. Mason
Nick Murphy
Benjamin Shenwick
Liam T. Ward

December 2015
# Table of Contents

1. Abstract .................................................................................................................. 1

2. The Renewable Fuel Standard ............................................................................. 2
   2.2 The Effect of the RFS on Emissions ................................................................. 2
   2.3 Biofuels Covered by the RFS ........................................................................... 4
      2.3.1 Cellulosic (D3) .......................................................................................... 5
      2.3.2 Biomass-based Diesel (D4) ......................................................................... 7
      2.3.3 Advanced Biofuels (D5) ............................................................................ 8
      2.3.4 Conventional Biofuel (D6) ......................................................................... 8
   2.4 Is the RFS Necessary? ....................................................................................... 8

3. Renewable Identification Numbers (RINs) ......................................................... 10
   3.1 Introduction and Purpose of RINs ................................................................. 10
   3.2 Pricing of RINs .............................................................................................. 11

4. Renewable Fuel Standard – 2016 Revision ....................................................... 14

5. E85 as a Solution ..................................................................................................... 16
   5.1 Introducing E85 .............................................................................................. 16
   5.2 The Blend Wall .............................................................................................. 16
   5.3 Factors Affecting Growth of E85 ................................................................... 17
      5.3.1 Addressing the Issue of Limited E85 Stations ......................................... 17
      5.3.2 Flex Fuel Vehicle Growth ....................................................................... 22
      5.3.3 Reducing Price of E85 ........................................................................... 27

6. Conclusion ............................................................................................................... 36

7. References ............................................................................................................. 38
1. Abstract

Since 2005, the government has established a minimum volume of ethanol consumption required in a calendar year. The Renewable Fuel Standards (RFS), most recently updated on November 30th 2015 by the Environmental Protection Agency (EPA), now outlines mandates through 2016. Our inquiry takes into account the most updated RFS volumetric thresholds. The purpose of this research is to model the nationwide demand in the US for E85 fuel and explore appropriate variances in E85 station number as well as in E10/E85 price ratio. In determining equilibrium points in our various models, we will demonstrate a scenario in which, under current economic conditions, society can properly meet and exceed the blend wall set forth by Renewable Fuel Standard (RFS) mandates.
2. The Renewable Fuel Standard


As a response to a growing concern for the protection of the environment and issues related to the sustainability of non-renewable fuel sources, the United States government enacted the Energy Policy Act of 2005. A main component of this act, and the topic central to this report, is the Renewable Fuel Standard (RFS). Briefly, the RFS mandates a certain amount of renewable fuel that must be blended into transportation fuel, as well as heating oil to lesser extent. In addition to its implementation by the Energy Policy Act of 2005, the RFS was expanded in 2007 under the Energy Independence and Security Act (EISA). The desire to reduce dependence on foreign energy sources, discussed in the EISA, directly led to an increase in the minimum volume of renewable fuel to be blended as mandated by the RFS. This subsequently led to increased production of corn ethanol as well as other renewable fuels, such as cellulosic ethanol and biomass-based diesel.¹

2.2 The Effect of the RFS on Emissions

The reduction in greenhouse gas (GHG) emission levels varies between the different renewable fuels. A gallon of corn ethanol, for instance, would reduce GHG emissions by 21% compared to a gallon of gasoline. Data for three renewable fuel types are given in Figure 1.

¹ http://www2.epa.gov/renewable-fuel-standard-program
<table>
<thead>
<tr>
<th>Renewable Fuel</th>
<th>EPA Estimate</th>
<th>EPA 95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Ethanol</td>
<td>21%</td>
<td>7 – 32%</td>
</tr>
<tr>
<td>Sugarcane Ethanol</td>
<td>61%</td>
<td>52 – 72%</td>
</tr>
<tr>
<td>Soybean Diesel</td>
<td>57%</td>
<td>22 – 80%</td>
</tr>
</tbody>
</table>

by 2022, percent fewer greenhouse gas emissions compared to an equal amount of gasoline.

The following is a graphic representation of the data above:

Figure 1

![Graph showing the estimated difference between the greenhouse gas emissions associated with various biofuels and the emissions associated with the gasoline or diesel they replace.

Figure 2

2.3 Biofuels Covered by RFS

In an effort to reduce GHG emissions, the RFS mandates a certain amount of specific renewable fuels based on their respective reductions in GHG emissions. The projected volumes of each type of fuel are displayed in the following figure.

![Renewable Fuel Standard Volumes by Year](chart.png)

The RFS categorizes renewable fuels into four groups: Cellulosic (D3), Biomass-based diesel (D4), Advanced (D5), and Conventional (D6). The benefits of D3, D4 and D5 are the increased GHG reduction compared to that of D6. Figure 4 on the following page illustrates the GHG reduction capabilities of each of the four categories.

---

3 http://www.afdc.energy.gov/laws/RFS
Through our analysis we have determined that conventional (D6) biofuels are the only RFS fuel source in which the possibility of implementation is probable, despite it being the least reductive in terms of GHGs. This is due to the impracticality of the other three categories. By this reasoning we will pursue models in which conventional biofuel can be better utilized in today’s society.

### 2.3.1 Cellulosic (D3)

Cellulosic (D3) biofuels are composed mainly of cellulose, the main component of plant cell walls. This organic substance can be composed from switchgrass, woodchips, and even from

---

4 http://energypolicy.columbia.edu/sites/default/files/energy/Renewable%20Fuel%20Standard_A%20Path%20Forward_April%202015.pdf
municipal waste. The defining factor in cellulosic biofuel is that it maintains a 60% or greater reduction in GHG in comparison to the average GHG lifecycle.⁵

Although a 60% reduction in GHG emissions would be beneficial, this concept is improbable given the current technology. The first issue is with regards to the cost of production, as “commercial cellulosic biofuel facilities are estimated to cost hundreds of millions of dollars, significantly more than a traditional corn ethanol plant, especially when measured in terms of the amount of biofuel produced”.⁶ Additionally, in 2013 the EIA predicted the cellulosic biofuel in comparison with the RFS mandate, and the results were less than convincing as demonstrated by Figure 5.

---


2.3.2 Biomass-based Diesel (D4)

Biomass-based Diesel (D4) is composed of biodiesel and cellulosic diesel. This category is in many senses a ‘cellulosic’ diesel. The EISA requirement for D4 is that it must be constructed from a renewable biomass rather than being processed in tangent with petroleum-based feedstock.⁷

In addition to the fact that D4 fuel can only be created using renewable biomass, it is barely produced in the US. The EIA reported in 2013 a record level of US biomass-based diesel imports as shown by the following figure.

The US does not have the profitable capabilities to produce this type of renewable fuel. Therefore this is not a plausible option for us to explore in our models.

---

⁸ https://www.eia.gov/todayinenergy/detail.cfm?id=16111
2.3.3 Advanced Biofuels (D5)

Advanced Biofuels, more commonly known as second-generation biofuels, are fuels that are manufactured from the organic element carbon. Second-generation biofuel is typically made from wood-like crops as well as agricultural waste. Although these biofuels have a 50% lifecycle reduction in GHG, it is difficult to extract the required fuel from advanced biofuel sources. This process is classified as Biomass-to-Liquid and can result in the emission of methane, which is a poor byproduct of a process that is supposed to limit GHG emissions.9

2.3.4 Conventional Biofuel (D6)

In discrediting the other three categories of biofuel presented, we are left with D6, otherwise known as conventional or first generational biofuels. Corn is the primary source of this ethanol-based fuel. This is advantageous because the entire corn plant can be used to create ethanol including the stalk and other seemingly useless parts. Additionally the infrastructure for harvesting and producing corn is already present in the US, making it the most probable and accessible method for renewable fuel production. In our following analysis, we will be addressing the increased usage of conventional biofuel (D6) in order to reach mandate specified in the RFS.

2.4 Is the RFS Necessary?

In the previous sections of this document, we speak to the benefits and the overwhelmingly positive effect the RFS will have on our environment. This topic is highly controversial and, while we do not wish to undermine the breadth and depth of this debate, we

assume that the RFS is a positive policy in order to create accurate models to reflect this policy. In this paper we will be reconciling an economy in which the RFS standards are desirable and beneficial to attain.
3. Renewable Identification Numbers (RINs)

3.1 Introduction and Purpose of RINs

In order to ensure compliance with the Renewable Fuel Standard, the EPA uses a system of Renewable Identification Numbers (RINs). Each gallon of renewable fuel produced is assigned a 38-digit RIN and each obligated party must ultimately retire a specific amount of RINs to the EPA in order prove they have met the Renewable Volume Obligation (RVO). The obligated parties, usually non-renewable fuel refiners or importers, can acquire RINs by purchasing the renewable fuel directly. The obligated parties can also purchase separated RINs as they are traded in the marketplace, similar to a commodity. The renewable fuel producer must sell the renewable fuel with the corresponding RINs attached. The RINs can only be separated after the renewable fuel is purchased by an obligated party or blended in fuel. The separated RINs can then either be retired to the EPA in order to meet the RVO or traded on the market. The EPA has developed a system – the EPA moderated transaction system (EMTS) – in order to monitor and regulate trading in the RIN market.\(^\textsuperscript{10,11,12}\)


\(^{12}\) [https://www.fas.org/sgp/crs/misc/R42824.pdf](https://www.fas.org/sgp/crs/misc/R42824.pdf)
3.2 Pricing of RINs

The system of Renewable Identification Numbers is the mechanism by which the EPA ensures compliance with the Renewable Fuel Standard; consequently, understanding the price of RINs is essential in evaluating changes to the RFS statutory volumes. Because the RIN system is market-based, RIN prices are effectively determined by market factors. A report by the EPA explains, “If the RIN market is functioning efficiently the RIN price should be approximately equal to the difference between a renewable fuel’s supply price and its demand price (the price the market is willing to pay for the renewable fuel as a transportation fuel).”\textsuperscript{11} If the RFS mandate requires an amount of renewable fuel to be blended that is greater than the market equilibrium, the RIN price reflects the incentive for the producer of the renewable fuel to produce beyond the amount prescribed by the natural market demand. As described, the RIN market is similar to a commodity market; therefore, the price of RINs depends on market fundamentals, as would the price of a commodity.\textsuperscript{4} In theory, the value of a RIN should be “the
difference between the price necessary to produce and distribute the mandated quantity of the
relevant biofuel and the price the consumer is willing to pay for it.”  

The RIN market can also be thought of as similar to a derivatives market of an asset or commodity, as the price of the RIN is ‘derived’ from the underlying renewable fuel, just as the value of an option is derived from the underlying asset. Some underlying factors influencing the price of RINs include: supply and demand of the respective renewable fuel, price of non-renewable transportation fuel, and consumer attitudes towards alternative fuel types.

In addition to retiring RINs accumulated during a specific year at the end of that year, an obligated party can also save and retire RINs in the following year, as long as RINs from the previous year do not exceed 20% of the current year RVO of the obligated party. This aspect of

---

the RIN system suggests that current prices also reflect future expectations of regulations and mandates of the RFS. Again the pricing of RINs resembles the pricing of a future or option contract, where the value depends on the current underlying market as well as expectations about the future. Thus, uncertainty about future regulation can lead to a rise in RIN prices.\textsuperscript{4}

\textbf{Figure 9}\textsuperscript{4}
4. Renewable Fuel Standard – 2016 Revision

On November 30, 2015, the EPA released an update to the Renewable Fuel Standard that included the 2016 renewable fuel mandate, finalized the 2014 and 2015 mandates, and provided an outlook for 2017 and beyond. The table below provides the volumes of specific biofuels, as well as total renewable fuels, that was blended in 2014 and 2015, and required to be blended in 2016.

Final Renewable Fuel Volumes:

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulosic biofuel (million gallons)</td>
<td>33</td>
<td>123</td>
<td>230</td>
<td>n/a</td>
</tr>
<tr>
<td>Biomass-based diesel (billion gallons)</td>
<td>1.63</td>
<td>1.73</td>
<td>1.90</td>
<td>2.00</td>
</tr>
<tr>
<td>Advanced biofuel (billion gallons)</td>
<td>2.67</td>
<td>2.88</td>
<td>3.61</td>
<td>n/a</td>
</tr>
<tr>
<td>Renewable fuel (billion gallons)</td>
<td>16.28</td>
<td>16.93</td>
<td>18.11</td>
<td>n/a</td>
</tr>
</tbody>
</table>

(Units for all volumes are ethanol-equivalent, except for biomass-based diesel volumes which are expressed as physical gallons.)

Although the recent mandates fall below the original projections of the EPA described earlier, the EPA has still facilitated a gradual increase in the amount of renewable fuel blended. The EPA will continue to take measures to ensure the growth of renewable fuel blending.15

Figure 11
5. E85 as a Solution

5.1 Introducing E85

E85 is an alternative fuel source that is already available at many fuel stations across the US. E85 ranges from a composition of 51 to 83% ethanol. The average gallon of E85 consists of 75% ethanol and 25% petroleum. This fuel type can only be used in Flex Fuel Vehicles (FFVs). Typical vehicles are only capable of using E10, a 10% ethanol composition fuel, as a fuel source.\(^\text{16}\)

5.2 The Blend Wall

On November 30\(^{\text{th}}\) 2015, the EPA released the final RFS mandate for 2014, 2015, and 2016.\(^\text{15}\) The most important aspect of the new mandate is the establishment of revised volumes that must be met through conventional biofuels (D6 ethanol). Every gallon of gasoline must now be blended with 10.09% ethanol on average in order to comply with the 2016 RFS standard. The EPA estimated that the total gasoline consumption in 2016 will be 140.05 billion gallons, resulting in a conventional biofuel requirement of 14.1 billion gallons of ethanol. Assuming 14 billion gallons of the approximately 14.1 billion will be consumed through E10, as E10 is typically comprised of 10% ethanol. The other 0.09% of the ethanol mandate can be fulfilled with E85 fuel consumption. In order to determine the amount of E85 necessary to overcome the blend wall, we take the ethanol content left to be consumed (126 million) and the assumption that E85 is 75% ethanol. Based on our calculation, the necessary volume of E85 needed to overcome the blend wall is 168 million gallons.

\(^{16}\) http://www.afdc.energy.gov/fuels/ethanol_e85.html
5.3 Factors Affecting Growth of E85

There are four significant factors preventing E85 from growing at a faster pace. Firstly, there are only 2990 gas stations selling E85. These stations are focused predominantly in the Midwest because of the many state incentives to refine and sell ethanol.\(^{17}\) Secondly, only FFVs can run on E85 and current fleet is underutilized by their owners. Thirdly, unless E85 is priced to reduce consumer fuel costs, there is only a niche group of people who will fill up with E85. Most individual do not internalize the externalities resulting from the use of E10 instead of E85 such as an increase in GHG emission and a reduced reliance on foreign gasoline. Thus, only people who have a strong interest in reducing GHG emission and environmentally conscious will purchase E85 when it is more expensive than E10. The expansion of E85 remains one of the most feasible options in surpassing the blend wall as discussed previously. In the following analysis we will explore models and suggest policy that will enable the US to surpass the current blend wall.

5.3.1 Addressing the Issue of Limited E85 Stations

One of the main factors inhibiting the more widespread use and overall growth of E85 is the limited number of stations capable of dispensing this fuel. In order to combat this limiting factor, more E85 capable pumps must be constructed. We will now address the specifics regarding this installation process and indicate how the current economic environment as well as policy changes would encourage and most likely result in an increased number of fuel stations carrying E85.

\(^{17}\) http://www.afdc.energy.gov/data/10332
There are many ways in which gas station owners can begin to sell and profit from the sale of E85, the most plausible of these methods is described in a report by National Renewable Energy Laboratory. The first option is to convert existing tanks already present at traditional stations into tanks that are capable of supporting E85. This option is only feasible if the individual station already has more than one E10 tank, as a station owner will not give up their only E10 tank for E85 and reduce their profit. Gas stations that have both E85 and E10 tanks can increase profits by selling whichever fuel is more attractive based on market prices. The conversion of an E10 tank to an E85 tank is estimated at a cost of $20,000. The second option is to completely install a new tank that would support E85 usage. This method would allow the station to maintain its current fuel tanks and is estimated to cost $60,000 per new tank. In both methods, it costs approximately $2,000 a month to maintain the new E85 equipment.\(^\text{18}\)

When this information was presented, a tax credit was awarded based on the EPAct of 2005, which has expired in 2009 (adherent to PUBLIC LAW 109–58 Section 1342 subsection G part 2 of the EPAct of 2005).\(^\text{19}\) We will be performing a similar calculation, however without this tax credit. The reasons for such are twofold, obviously the tax credit is no longer current, and additionally a more streamlined calculation will allow our own investigation to implement policies different then a simplistic bulk tax credit. We will first execute the calculation and then implement policy in order to attain our desired result.

In order to determine the gross margin on E85 to ensure it is a logical investment for gas station owners, we altered the NREL’s model so that it no longer includes the federal infrastructure tax credit, which was part of the EPAct of 2005 and expired in 2009. Assuming

\(^\text{18}\) http://www.afdc.energy.gov/pdfs/42061.pdf
that we maintain the NREL’s baseline assumptions, we can back out the margins without a federal tax credit. The profit can be found by multiplying the margin per gallons sold and the total number of gallons sold. Assuming an ROI of 10% we know the total investment required for the project. We then add back the money that was previously saved on the subsidy, $6,000 for converted tanks or $18,000 for new units, to the total investment value. From there, we find the value of a 10% return on investment (ROI) and divide by 70,000 gallons to determine the new gross margins. We find that the gross margins for converted stations are $0.16 and $0.22 for new stations. The subsidy provided even greater savings for the installation of new infrastructure; however, it provided no incentive for the station to actually sell the E85 fuel to consumers.

In the following model, we explore instituting a subsidy per gallon in order to increase ROI for the creation of E85 tanks and to increase actual E85 usage by consumers. This model demonstrates how small increases in a per gallon sold tax subsidy would increase ROI in correlation to the magnitude of the subsidy shown in Figure 12.
Policy implementation of a per gallon sold tax credit will be much more beneficial than the previous lump sum credit. This concept will force stations to increase their physical sales of E85 rather than simply converting their tanks. The main profit driver will be the sale of E85. This will lead to better advertising and publicity regarding E85 as stations will desire to sell more E85 so they can receive the per gallon subsidy. The implementation of our subsidy rather than the lump sum tax credit provided in the study by the NREL is a policy that would directly impact the gas industry’s desire to create new tanks, and actually sell E85. Although this is a simplified model, this policy intervention would lead to an increase in stations offering E85 and the number of gallons sold per station throughout the country.

Even without our policy to increase stations selling E85, data has shown that the number of E85 stations has been growing at a rate of 5% annually. In an Iowa State policy brief, Bruce Babcock and Sebastien Pouliot illustrate the potential demand for E85 assuming it becomes more attractively priced relative to E10. The market for E85 is currently underserved because supply is limited due to the lack of stations selling E85. Since the supply of stations is capped, the current equilibrium E85 demand is below the potential equilibrium achieved by our policy. Our policy will increase the supply of E85 stations creating a new equilibrium where quantity of E85 sold increases and the price per gallon is reduced. These alternative fuel stations are too far and few between (as illustrated by Figure 13) for areas with high FFV ownership, and therefore there is unserved demand for E85 fuel. This is yet another incentive for more alternative fuel stations to enter the industry. Locations that are highly populated with FFVs but cannot supply the fuel are great locations for stations to either create new tanks or transform old ones as discussed previously. Pointing to a specific example, the state of Texas has only 81 E85 fuel stations that

20 https://www.card.iastate.edu/policy_briefs/display.aspx?id=1188
are supposed to serve over 1.6 million FFVs.\textsuperscript{21} This leaves a large opportunity for firms to enter the market given that E85 is priced competitively with E10.

\begin{figure} 
\centering
\includegraphics[width=\textwidth]{map.png}
\caption{Figure 13} 
\end{figure}

One aspect that would grossly hinder the benefits of installing new fuel tanks would be if the installation process took in excess of a year, which would hinder our policy from breaking the blend wall in 2016. However, the full replacement of underground fuel storage tanks takes only about 6 weeks,\textsuperscript{23} and a conversion of an already existing tank could take as few as three days.\textsuperscript{24} This short turnaround in installation or conversion, the profitability of E85 given our imposed policy, and the presence of excess demand for E85 address how the blend wall can be broken through the installation of E85 stations.

\begin{itemize}
\item \textsuperscript{21} https://www.card.iastate.edu/policy_briefs/display.aspx?id=1213
\item \textsuperscript{22} http://www.card.iastate.edu/policy_briefs/display.aspx?id=1187
\item \textsuperscript{23} http://articles.orlandosentinel.com/2009-12-29/business/os-underground-tanks-20091229_1_gas-stations-double-walled-tanks-underground-fuel-storage
\item \textsuperscript{24} http://www.afdc.energy.gov/pdfs/41590.pdf
\end{itemize}
5.3.2 Flex Fuel Vehicle Growth

There are a large and growing number of FFVs in the US being produced by American automakers. As presented in the example regarding the state of Texas, the number of FFVs is actually outrunning the number of available stations to fuel them with E85. We were able to find sources chronicling the amount of FFVs on the road and from such constructed the graph shown in Figure 4 illustrating the FFVs in the US as well as the percentage that these FFVs make up in relation to the overall vehicle population. In determining the percentage of FFV on the road over the past 4 years we used data from the US department of Transportation as well as the Federal Highway Administration to determine the number of vehicles registered in the US over those same years.  

The number of FFVs in the US was then used to determine the percentage of FFVs on the road.

---

This graph indicates a strong upward trend in FFV production and FFV sales as a percentage of total cars on the road. In order to address the likelihood of reaching the standards set by the RFS, it is important to determine whether the observed trend will prove to be continuous and ongoing. The Fuels Institute, a research entity dedicated to discovering sustainable transportation energy solutions, came up with the following volumetric FFV projection based off of a year-to-year growth ratio modeled off of the constant FFV growth we have seen in prior years. This model, pictured in Figure 15, predicts a continual upkeep in the number of FFVs in the US.
It is important to evaluate the quality of the vehicles produced by the auto industry rather than just observe the volume of FFVs sold. In 1975 the Corporate Average Fuel Economy Standard (CAFE) was passed in order for the government to properly regulate the fuel economy of vehicles. The CAFE standard requires that automakers produce a certain number of passenger vehicles that exhibit specified fuel economy guidelines. The National Highway Traffic Safety Administration is working to have this mandatory fuel economy raised in addition to the fines associated with violating the standard. The current penalty is only $55 per car, which many automakers simply write off as a cost of production. The automakers that want to avoid this fine per vehicle choose at large to produce many of their vehicles with FFV capabilities, allowing them to pass CAFE standards. The problem with this is that automakers are simply producing FFVs in order to avoid fines rather than improving the efficiency of these FFVs. This could be done by increasing the mileage that can be attained using E85. Therefore, the auto industry is not strongly incentivizing the potential car buyers to purchase FFVs, as E85 is often more expensive on a cost per mile basis than gasoline. Although automakers may think they are

Figure 15

http://www.cmu.edu/gdi/docs/a-structural-analysis.pdf
avoiding a government regulation, they are in reality only limiting the FFV industry by not maximizing the potential E85 fuel consumption, which would lead to increased FFV sales.

The following statistic is indicative of the disinterest that the auto industry has been showing with regard to the fuel economy of FFVs. According to the US Department of Energy, there were approximately 863,000 Flex Fuel Fleet Vehicles that were regularly fueled with E85 in 2014. Flex Fuel Fleet Vehicles are extremely large groups of vehicles used by the government and other large institutions. These vehicles make up a large part of the FFV population because they are owned and operated by the government or a business. These entities have a much higher likelihood of being regulated by a board or other management that would be concerned with the fuel economy of their vehicles in relation to the environment with the idea of keeping public opinion positive regarding a particular entity. For the purpose of this paper, we assume that 25% of the vehicles in the US are fleet vehicles, bringing the total number of vehicles to 3.34 million. By these calculations, only 25% of Flex Fuel Fleet Vehicles are fueled regularly with E85. That means that 75% of all Flex Fuel Fleet Vehicles are using E10 and have only been produced in order for manufacturers to save money on research and development in their FFV tanks. This calculation illustrates the necessity for a policy implementation that better regulates the production side of this issue. If the automakers actions continue to go unregulated, FFVs will continue to be produced to avoid fines and will not help in the US effort to reduce emissions and enable ethanol usage to increase so that we may surpass the blend wall.

In order to achieve a scenario in which consumers will choose to fuel their FFVs with E85, we must implement a change to the CAFE standards. Rather than simply having to reach a particular fuel economy per vehicle, a standard must be established by which the auto industry is

---

responsible for increased cost efficiency in the use of E85. We propose a policy in which the automaker would be forced to, upon inspection of vehicles from their dealerships during routine checks, examine fuel tanks for a particular amount of E85 usage and record the data. The standard would then be determined based off of the amount of E85 actually used in their vehicles rather than if their vehicles could simply handle the fuel. Through this policy automakers will be forced to create better tanks that can maintain a comparable cost per mile to E10 with E85 fuel.

This is a realistic proposal as the technology necessary to accomplish this task already exists. In a study done regarding the corrosion of copper and steel alloys in relation to large underground fuel storage tanks, corrosion was simulated through the introduction of a particular bacteria. Obviously the amount of corrosion was measureable. Quartz-crystal microbalances (QCM) were used and mounted into a crystal holder. This holder measured the frequencies of the QCMs over time until the frequency could no longer be observed due to corrosion. This technology is a simplistic method by which the auto industry could measure the corrosion due to the use of high ethanol volume fuel. In measuring the corrosion the auto industry could be forced to maintain a particular level of actual E85 usage forcing them to make E85 more desirable to their customers in terms of fuel efficiency and cost per mile in comparison with regular gasoline.

Through our policy implementation, we can force the auto industry to think about and finally take action on the environmental issues outlined by the RFS. The creation of more fuel efficient FFVs will result in the duel effect of increased FFV vehicles and E85. This policy along with the creation of a cheaper and more accessible E85 supply will enable the US to overcome the blend wall and cooperate with RFS standards.

5.3.3 Reducing Price of E85

The growth of E85 has been hindered by the limited number of available alternative fuel stations and by the short-term focus of the auto industry. Both of these analyses point to the same solution: reducing E85 price at the pump. With a lower E85 price, stations will want to sell more gallons of E85 in order to increase their benefit from the per gallon subsidy as described previously. This will result in an increased number of stations as the E85 station market becomes profitable due to unserved demand. Additionally, if automakers are forced to monitor the fuel intake of their vehicles they will benefit from reduced E85 prices as it will help them reach standards and avoid fines. In summation, the reduction in E85 fuel price is an instrumental factor in our economy’s ability to increase ethanol consumption and surpass the blend wall given the current scenario. In terms of our analysis we will not be calculating a specific price per sé, but instead the ratio of E10 to E85 prices in order to represent the necessary discount to satisfy nationwide demand.

To determine the price ratio that will satisfy E85 demand, we begin by examining demand for E85 as the price ratio of E85 to gasoline changes. Research has been done estimating demand for ethanol as a gasoline substitute.\(^31\) Anderson uses the state of Minnesota’s ethanol and gasoline consumption data in order to create a model estimating E85 demand. He estimates that demand for ethanol as a gasoline substitute has an average elasticity between 2.5-3.5. Additionally, he found that many households are willing to pay a premium for ethanol and gasoline. He finds that 13% of FFV owners choose ethanol when the price ratio averaged 1.14. Many households prefer E85 on a cost per mile basis because that means any policy implementation would not need to be as severe and would cause less market distortion.

\(^{31}\) http://www.nber.org/papers/w16371.pdf
Additionally, in one poll more than 90% of drivers stated they have a preference for FFVs because they use “renewable fuel”, are “more economical” and are made in America.\cite{Phoenix2006} This preference toward FFVs bodes well for the expansion of E85 usage.

We are able to model domestic E85 consumption using Anderson’s research and Minnesota’s Department of Commerce E85 data. We estimate total 2015 ethanol consumption in Minnesota by multiplying the average E85 monthly sales, the total average number of stations in Minnesota, and scaling the result by 12 months. This gives a total of 14.8 million gallons of ethanol consumed per year. We know that in Minnesota the average price ratio of E10/E85 is 1.31, which means that E10 and E85 are priced at a parity on a cost per mile basis. We then evaluate different price ratios of E10/E85 using the elasticity for Minnesota Fuel found by Anderson using the current 2015 Minnesota data (price ratio of 1.31 and 14.8 million gallons of E-85 consumed). The current price ratio of E10/E85 in the US is 1.122 according to E85prices.com indicating that E85 is more expensive than E10 on a cost per mile basis and thus demand for E85 domestically is not very high. We can therefore determine the total demand for ethanol in Minnesota assuming the price ratio was the same as the US. This implies Minnesota’s E85 consumption would be 9.2 million gallons annually for the state or 32,274 gallons of E85 per station. From here we can multiply E85 sales per station by total number of stations to get a rough estimate of 2015 E85 consumption.

We also modeled ethanol demand at differing E10/E85 prices, assuming that elasticity changes over time, as shown in Figure 16. According to Anderson, average elasticity at the margin is between 2.5-3.5; however, it is unlikely that the elasticity is around three in the corners, where the E10/E85 price ratio is high or low. At the margin, the E10/E85 price ratio is approximately 1.30 and the cost per mile is equivalent because ethanol is 77% as efficient as E10 (ethanol contains approximately two thirds the energy value of gasoline). We will assume that E85 is composed of 75% ethanol and 25% gasoline and E10 is composed of 10% ethanol and 90% gasoline. Therefore the efficiency ratio of E85 over E10 is equal to:

$$\frac{\left(75 \times \frac{2}{3} + 25 \times 1\right)}{0.1 \times \frac{2}{3} + 0.9 \times 1} = 0.77$$

This means that 1 gallon of E85 will allow a vehicle to travel 77% of the distance that a vehicle could travel on E10. Ethanol when viewed as a substitute for fuel has a greater elasticity than at the extremes because it reduces costs. If the entire population was homogenous and cared solely about prices then the elasticity would be infinite at the margin and 0 everywhere else since
everyone would buy the cheaper fuel. It is unlikely that anyone would switch from E10 to E85 if the E10/E85 price ratio is well below one and varies by a nominal value, meaning ethanol is more inelastic when the price ratio is extreme.

Therefore, we modeled E85 consumption for different price ratios assuming elasticity decreased as the price ratio moves away from the margin. We found that the demand for E85 in Minnesota, assuming a variable elasticity, is 11.1 million gallons a year. Using the same process as described in the paragraph above we determine that the total consumption of E85 in the US in 2015 will be 116 million by scaling the data from the Minnesota fueling station. We believe extrapolating from the Minnesota E85 data is appropriate due to the unserved demand for E85 as there are 5819 Flex Fuel Vehicles per E85 station in the US.

Since we now have a model to measure the relationship between E10/E85 price ratio and total national demand, we must determine an appropriate ratio to utilize in an upscale to total demand. A study done by AJW Inc. using data comprised from E85prices.com summarized the same-station price discount for both major market and individual stations, shown in Figure 17 below.\(^{33}\)

![E85 Retail Discount - National Averages](image)

\(^{33}\) AJW
Using AJW’s most recent E85 discount relative to E10 of 17% (as shown in Figure 17) in our model above, we utilize a ratio of 1.20. Using the ratio provided by the AJW’s research E85 discount our model predicts 127 million gallons of E85 demand. This is our estimate assuming that all stations nationwide (2990 E85 fuel stations) can operate at the price ratio achieved by independent brand stations as discovered by AJW Inc.\textsuperscript{33} If we hold the total number of stations constant our model predicts a domestic E85 demand of 170 million gallons. These numbers only exist in a scenario where the number of stations remains constant and we fix the price ratio at 17%. We will see in the following experiment that both of these variables can be modeled to achieve E85 volumes that surpass the blend wall set forth by the new EPA mandates.

In order to determine how E85 can break the blend wall we created a sensitivity table, shown in Figure 18, that varies both the number of E85 capable stations countrywide along with E10/E85 price ratios. Each value within the chart was calculated in the same method as the calculation for 2990 stations and a ratio of 17% as demonstrated in the previous paragraph. Within the sensitivity table, all green values are greater than the blend wall set forth by the EPA. This demonstrates that there are numerous combinations that will allow the US to overcome the blend wall.
We determine three cases of station growth and model each one in terms of the particular price ratio that will result in E85 usage overcoming the blend wall. We illustrate models that have 0% growth in alternative fuel stations (Figure 19), 5% growth (Figure 20), and 25% growth (Figure 21).

<table>
<thead>
<tr>
<th>Percent Change in Station Volume</th>
<th>1.1 (9%)</th>
<th>1.15 (13%)</th>
<th>1.2 (17%)</th>
<th>1.25 (20%)</th>
<th>1.3 (23%)</th>
<th>1.35 (26%)</th>
<th>1.4 (29%)</th>
<th>1.45 (31%)</th>
<th>1.5 (33%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5%</td>
<td>101.26</td>
<td>103.55</td>
<td>105.98</td>
<td>108.51</td>
<td>111.13</td>
<td>113.88</td>
<td>116.77</td>
<td>119.80</td>
<td>122.97</td>
</tr>
<tr>
<td>No Change</td>
<td>113.86</td>
<td>119.03</td>
<td>126.97</td>
<td>134.01</td>
<td>152.69</td>
<td>170.47</td>
<td>186.25</td>
<td>199.56</td>
<td>209.88</td>
</tr>
<tr>
<td>5%</td>
<td>125.24</td>
<td>130.93</td>
<td>139.66</td>
<td>151.81</td>
<td>167.96</td>
<td>187.52</td>
<td>204.88</td>
<td>219.51</td>
<td>230.87</td>
</tr>
<tr>
<td>10%</td>
<td>130.93</td>
<td>136.89</td>
<td>146.01</td>
<td>158.71</td>
<td>175.59</td>
<td>196.04</td>
<td>214.19</td>
<td>229.49</td>
<td>241.36</td>
</tr>
<tr>
<td>20%</td>
<td>136.63</td>
<td>142.84</td>
<td>152.36</td>
<td>165.61</td>
<td>183.23</td>
<td>204.56</td>
<td>223.51</td>
<td>239.47</td>
<td>251.86</td>
</tr>
<tr>
<td>25%</td>
<td>142.32</td>
<td>148.79</td>
<td>158.71</td>
<td>172.51</td>
<td>190.86</td>
<td>213.09</td>
<td>232.82</td>
<td>249.45</td>
<td>262.35</td>
</tr>
<tr>
<td>30%</td>
<td>148.01</td>
<td>154.74</td>
<td>165.06</td>
<td>179.41</td>
<td>198.49</td>
<td>221.61</td>
<td>242.13</td>
<td>259.43</td>
<td>272.84</td>
</tr>
<tr>
<td>35%</td>
<td>153.71</td>
<td>160.69</td>
<td>171.40</td>
<td>186.31</td>
<td>206.13</td>
<td>230.14</td>
<td>251.44</td>
<td>269.40</td>
<td>283.34</td>
</tr>
<tr>
<td>40%</td>
<td>159.40</td>
<td>166.64</td>
<td>177.75</td>
<td>193.21</td>
<td>213.76</td>
<td>238.66</td>
<td>260.76</td>
<td>279.38</td>
<td>293.83</td>
</tr>
<tr>
<td>45%</td>
<td>165.09</td>
<td>172.59</td>
<td>184.10</td>
<td>200.11</td>
<td>221.40</td>
<td>247.18</td>
<td>270.07</td>
<td>289.36</td>
<td>304.33</td>
</tr>
<tr>
<td>50%</td>
<td>170.78</td>
<td>178.55</td>
<td>190.45</td>
<td>207.01</td>
<td>229.03</td>
<td>255.71</td>
<td>279.38</td>
<td>299.34</td>
<td>314.82</td>
</tr>
<tr>
<td>100%</td>
<td>227.71</td>
<td>238.06</td>
<td>253.93</td>
<td>276.01</td>
<td>305.38</td>
<td>340.94</td>
<td>372.51</td>
<td>399.12</td>
<td>419.76</td>
</tr>
</tbody>
</table>

*All data within table is in millions*

**Figure 18**

We determine three cases of station growth and model each one in terms of the particular price ratio that will result in E85 usage overcoming the blend wall. We illustrate models that have 0% growth in alternative fuel stations (Figure 19), 5% growth (Figure 20), and 25% growth (Figure 21).
Price Ratio Required to Break Blend Wall
Assuming 5% increase in Gas Stations

Price Ratio Needed to Break Blend Wall: 1.32

Price Ratio Required to Break Blend Wall
Assuming 25% increase in Gas Stations

Price Ratio Needed to Break Blend Wall: 1.25
Figure 20 shows the 5% station growth model. This model is what we expect to happen given the current average annual station increase without implementing any specific policy change that would induce the creation of an excess amount of E85 capable stations. Figure 12 illustrates this steady 5% increase over the past 10 years.

Although we can break the blend wall at the 5% station growth pace and an E10/E85 ratio of 1.32, we would like to implement a policy to even further reduce the parity in prices in order to encourage producers to sell E85 and consumers to purchase it in a stable economy. In conjunction with the implementation of our station policy in the previous section, a 25% increase in stations is plausible and would meet the unserved demand present in the economy with an even smaller discount of E85 relative to E10. With a 25% increase in E85 stations, the price ratio drops to 1.25. Customers will not be required to travel as far to reach E85 fueling stations and station owners will be enticed to sell E85, as they stand to profit further. As the number of E85 stations increases, the discount of E85 relative to E10 does not have to be as large, leading to higher ethanol prices and increased production.
It is important to understand the impact of setting an E85/E10 ratio on the RIN market.\textsuperscript{34} Since E10 currently costs $2.08 a gallon,\textsuperscript{35} E85 would have to retail for $1.38 a gallon in order to generate a 10% cost per mile basis. By regressing retail gasoline price on wholesale gasoline prices using the formula $y = ax + b$ we approximate that the retail markup on ethanol to be 75. This would imply that E85 would wholesale for $0.63 a gallon. Since wholesale gasoline costs approximately $1.33 a gallon meaning that ethanol would cost $0.22 per gallon assuming that E85 contains 75% ethanol. In this scenario RINs would be valued at the difference between the required price of ethanol needed for a 10% E85 discount on a cost per mile basis and the cost of producing ethanol in the plant. Any further discount to the required ethanol price would lead to a further increase in the RIN price in order to subsidize the lower fuel price. The impact of reducing the cost of ethanol below its natural price is an increase in RIN prices, which is, in essence, a subsidy for the production of ethanol.

\textsuperscript{34} http://www.card.iastate.edu/publications/dbs/pdffiles/13pb12.pdf
\textsuperscript{35} http://www.e85prices.com
6. Conclusion

We explore different options for increasing ethanol production in order to surpass the conventional biofuel mandate enforced by the EPA, known as the blend wall. We identify three reasons why ethanol consumption has been lackluster and propose policy changes that provide solutions to the issue. Our proposals aim to increase ethanol consumption through the expansion of E85 usage.

Firstly, we determined that the gross margins required for a gas station to reconfigure a gas tank to hold E85 or build a new gas tank is $0.16 and $0.22 respectively, assuming an ROI of 10%. We proposed a policy by which the government subsidizes E85 sales per gallon after a tank is reconfigured or installed. This will incentivize gas station owners to install new E85 tanks by increasing their ROI and encourage E85 advertising.

Secondly, we observed trends in the FFV industry and found that the number of flex fuel vehicles has been increasing by 5% annually. However, it is apparent that auto makers are only selling FFVs in attempt to comply with CAFE standards, without investing in the improvement of E85 fuel efficiency. Therefore, auto makers are reducing E85 consumption because the people purchasing cars are filling their cars with E10 instead. We propose that CAFE should be changed to ensure that automakers are accountable for E85 consumption rather E85 compatibility.

Thirdly, using the state of Minnesota’s E85 data we estimated potential US ethanol consumption under different scenarios to determine that we can break the blend wall. We build a sensitivity table with varying numbers of new gas stations and differing discounts of E10 relative
to E85. We observed that as the number of gas stations increased the discount rate decreased. One case we determined reasonable in achieving the conventional biofuel mandate in 2016 of 126 million gallons of ethanol is a 25% increase in E85 stations and an E10/E85 price ratio of 1.25. Our three pronged policy should increase E85 station count and incentivize FFV owners to consume more E85 fuel, allowing the US to break the blend wall.
7. References


