

How Much Ethanol Can Be Consumed in E85?

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Executive Summary

EPA's justification for proposing to reduce ethanol mandates in the Renewable Fuel Standard (RFS) is that consumer demand for ethanol is not high enough to meet the original targets. About 13.7 billion gallons of ethanol can be consumed in E10, which contains 10% ethanol. The original mandate for conventional biofuel (widely assumed to be corn ethanol) was supposed to increase to 15 billion gallons in 2016. This would require that 1.3 billion gallons of ethanol would need to be consumed in gasoline-ethanol blends that contain more than 10% ethanol. The two blends that contain more than 10% ethanol approved for sale are E15 and E85. The number of stations that sell E15 is currently quite small whereas almost 3,000 stations sell E85. Thus EPA focuses on the contribution of potential E85 sales to make its claim that there is insufficient demand for ethanol to support a mandate of 15 billion gallons.

EPA writes in its proposed rule: "Thus we believe it is possible for the market to reach volumes perhaps as high as 600 million gallons under favorable pricing conditions" (p. 61). Adding this 600 million gallons to 13.7 billion gallons of ethanol consumed in E10 means that EPA believes that a maximum of 14.3 billion gallons of ethanol can be consumed in the United States. This is why EPA proposes to reduce mandates for the non-advanced biofuel from 15 to 14 billion gallons in 2016.

Estimation of the demand for E85 requires data matching various E85 price levels with the corresponding amount of E85 sales. A rich source of data was provided to us that we used to estimate directly the proportion of U.S. owners of flex vehicles who buy E85 at various price points. The data contains daily station fuel sales and prices of a major Midwest chain of retail gasoline outlets. We report on how owners of flex vehicles in two metropolitan areas respond to changes in the price of E85 and extrapolate the results to the national level. Perhaps uniquely, this chain's aggregate market share in these two metro areas was much greater than 90%, thus allowing us to estimate the proportion of owners of flex vehicles in the area who chose to switch from E10 to E85 at various price levels. Using these new direct estimates of consumer demand, we find that owners of current flex vehicles in all US metro areas would consume 250 million gallons of E85 if it was priced at parity on a cost per mile basis with E10, and one billion gallons of ethanol if E85 were priced to save drivers 23% on a cost per mile basis. These estimates assume that no new E85 stations are installed. If new stations were installed so that drivers in metro areas had the same driving distance to an E85 station as drivers do in one of our study

areas, then more than one billion gallons of ethanol would be consumed in E85 in US metro areas if E85 were priced to save FFV drivers 10% on a cost per mile basis. These estimates significantly understate total US E85 consumption because consumption in non-metro areas is not included.

Our results show that meeting the original 15 billion gallon RFS ethanol target in 2016 is feasible. The two key conditions needed to meet this consumption level is to allow the market for RINs to work as intended, which will allow the price of E85 to fall to induce consumers to buy the fuel, and for EPA to set a consistent policy signal to industry that they will indeed have to meet this target. A clear and consistent message from EPA is needed to foster investment in fueling stations that will allow enough consumers to access E85.

How Much Ethanol Can Be Consumed in E85?

EPA's justification for proposing to reduce ethanol mandates is that the supply of ethanol that consumers will use is less than original mandates specified in the Renewable Fuels Standard. Using more straightforward language, EPA believes that consumer demand for ethanol is not high enough to meet the original targets. The US Energy Information Agency (EIA) pegs current US consumption of gasoline at about 137 billion gallons. Nearly all of this gasoline contains 10 percent ethanol (E10). Thus, as much as 13.7 billion gallons of ethanol can be consumed in E10. The original mandate for conventional biofuel (widely assumed to be corn ethanol) was supposed to increase to 15 billion gallons in 2016. This would require 1.3 billion gallons of ethanol consumption in gasoline-ethanol blends that contain more than 10 percent ethanol. The two blends that contain more than 10 percent ethanol approved for sale are E15 and E85. The number of stations that sell E15 is currently quite small, whereas almost 3,000 stations sell E85. Thus, EPA focuses on the contribution of potential E85 sales to make its claim that there is insufficient demand for ethanol to support a mandate of 15 billion gallons.

EPA writes in its proposed rule: "Thus, we believe it is possible for the market to reach volumes perhaps as high as 600 million gallons under favorable pricing conditions" (p. 61). Adding this 600 million gallons to 13.7 billion gallons of ethanol consumed in E10 means that EPA believes that a maximum of 14.3 billion gallons of ethanol can be consumed in the United States. This is why EPA proposes to reduce mandates for the non-advanced biofuel from 15 billion to 14 billion gallons in 2016.

In a study that we conducted in 2014, we estimated that, under favorable pricing, consumers would buy no more than one billion gallons of ethanol in E85 given no change in the fueling infrastructure.¹ Our estimate relied on a number of modeling assumptions that were required to estimate US consumer response to changes in E85 prices. One key assumption that we made was that US owners of flex fuel vehicles (FFVs) would switch from E10 to E85 similar to Brazilian FFV owners switched from gasoline (which contained between 20–27 percent ethanol) to E100. However, Brazilian consumers have much more experience choosing between alternative fuels than US consumers—more than half of Brazilian cars are FFVs and all stations have had to sell

¹Pouliot, S. and B.A. Babcock. "The Demand for E85: Geographical Location and Retail Capacity Constraints." *Energy Economics* 45(2014):134-143.

both E100 and gasoline for many years. In addition, we had to make assumptions about the distance that owners of FFVs had to drive to find a station that sold E85 in order to estimate the required E85 price discount that would be needed to cover the cost of a special trip.

After we conducted our 2014 study, we obtained access to a rich and relevant data source that allows us to directly estimate the proportion of US owners of FFVs who buy E85 at various price points. The data contains daily station fuel sales and prices of a major Midwest chain of retail gasoline outlets and covers sales of all stations from 2011 through 2014. During this time period the price of E85 relative to E10 has varied dramatically, allowing us to trace out how consumption of E85 varies with price. Here we report on how owners of FFVs in two metropolitan areas respond to changes in the price of E85. Perhaps uniquely, this chain's aggregate market share in these metro areas was much greater than 90 percent, thus allowing us to estimate the proportion of owners of FFVs in the area who chose to switch from E10 to E85 at various price levels. Using these new direct estimates of consumer demand, we find that owners of current FFVs in all US metro areas would consume 250 million gallons of E85 if it was priced at parity on a cost-per-mile basis with E10, and one billion gallons of ethanol if E85 were priced to save drivers 23 percent on a cost-per-mile basis. These estimates assume that no new E85 stations are installed. If new stations were installed so that drivers in metro areas had the same driving distance to an E85 station as drivers do in one of our study areas, then more than one billion gallons of ethanol would be consumed in E85 in US metro areas if E85 were priced to save FFV drivers 10 percent on a cost-per-mile basis. These estimates significantly understate total US E85 consumption because consumption in non-metro areas is not included.

Data Needed to Estimate E85 Demand

Much of the debate about the potential for using E85 as a way of meeting expanded ethanol mandates arises from uncertainty about how willing US drivers are to switch from E10 to E85. Switching is only possible for current owners of FFVs. Because potential demand in a region is limited by the number of FFVs owned in that region, data on FFV ownership is needed for any study region. As part of this study, we purchased data that reports ownership of FFVs by US zip code for the entire United States as of January 1, 2015. Figure 1 shows where FFVs are located. Not surprisingly, they are located where people live in metropolitan areas. This data set shows that 18 million FFVs were registered in the United States.

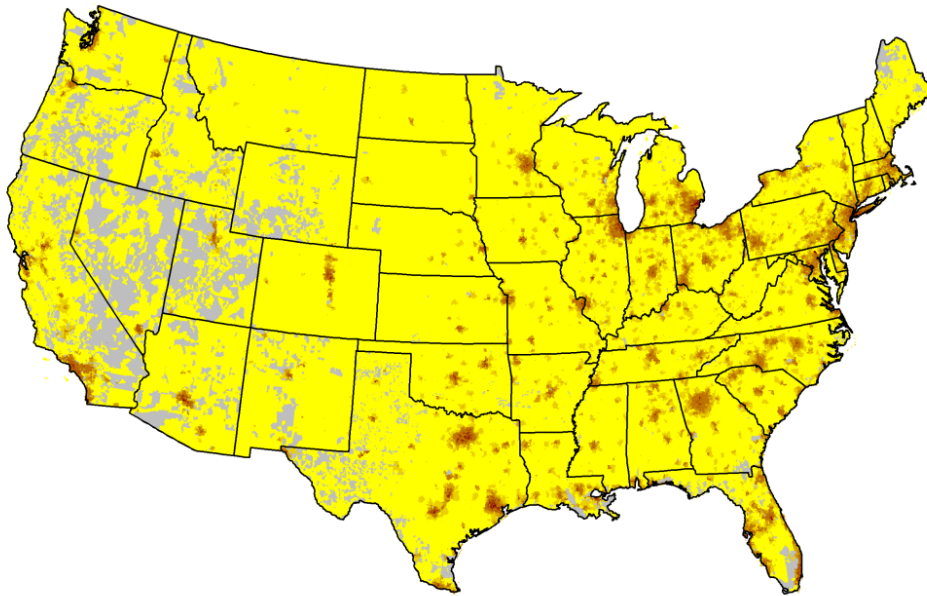


FIGURE 1. Density of FFVs

Note: Yellow indicates a low concentration of FFVs and a darker shade of red indicates greater concentration. The areas in grey indicate that no data were available.

The second factor that affects the amount of E85 consumed is its price relative to E10. Because E85 contains about 78 percent as much energy as E10, a car travels approximately 22 percent fewer miles on a gallon of E85 than on E10. Thus, the cost per mile traveled on E85 is greater than on E10 unless the pump price of E85 is 22 percent lower than the pump price of E10. It seems reasonable to assume that most owners of FFVs will not want to switch to E85 unless it saves them money. It is difficult to estimate the demand for E85 without sales data that has been generated when E85 is attractively priced for consumers.

One way that E85 can be attractively priced is if the price of ethanol that is blended with gasoline reflects the price of RINs (Renewable Identification Numbers). RINs are tradable permits that are generated and sold with each gallon of ethanol produced. Buyers of ethanol who blend it with gasoline can separate the RIN from the ethanol at blending. The separated RIN can then be used for compliance with blending requirements or it can be sold on the RIN market. To see why a high RIN price can make E85 attractively priced, suppose that the wholesale price of ethanol at a blending station is \$2.00 per gallon and the RIN price is \$0.50 per gallon. The blender pays \$2.00 for the ethanol and the attached RIN. To break-even on the transaction, the

blender can sell the RIN for \$0.50 and price the ethanol in the blended fuel at \$1.50 per gallon. If the gasoline in the blended fuel costs \$2.00, the blender can create E85 (75 percent ethanol and 25 percent gasoline) at a break-even cost of \$1.625 per gallon, and E10 at a break-even cost of \$1.95. Thus, at the wholesale level, the E85 can be priced 16.7 percent lower than E10. If the RIN price increases to \$0.75 per gallon, then the break-even price of E85 is \$1.44, which is 25 percent lower than the break-even price of E10. Thus, a higher RIN price makes it possible to price E85 at levels that are attractive to consumers.

Figure 2 shows the ratio of a calculated wholesale price of E85 to a calculated wholesale price of E10 based on observed futures prices for gasoline and ethanol and the reported price of RINs. Since March of 2013, the RIN-adjusted price of E85 has usually been low enough to make the cost per mile of running an FFV on E85 lower than on E10. However, this “theoretical” wholesale price of E85 will not reflect the actual price that consumers pay unless there is sufficient competition between oil companies, between gasoline blenders, and between retailers to ensure that RIN prices are fully reflected in the price that consumers pay at the pump. In addition, taxes and markups that are imposed on a per-gallon basis will have a greater proportionate impact on the wholesale-to-retail price spread of E85 than E10.

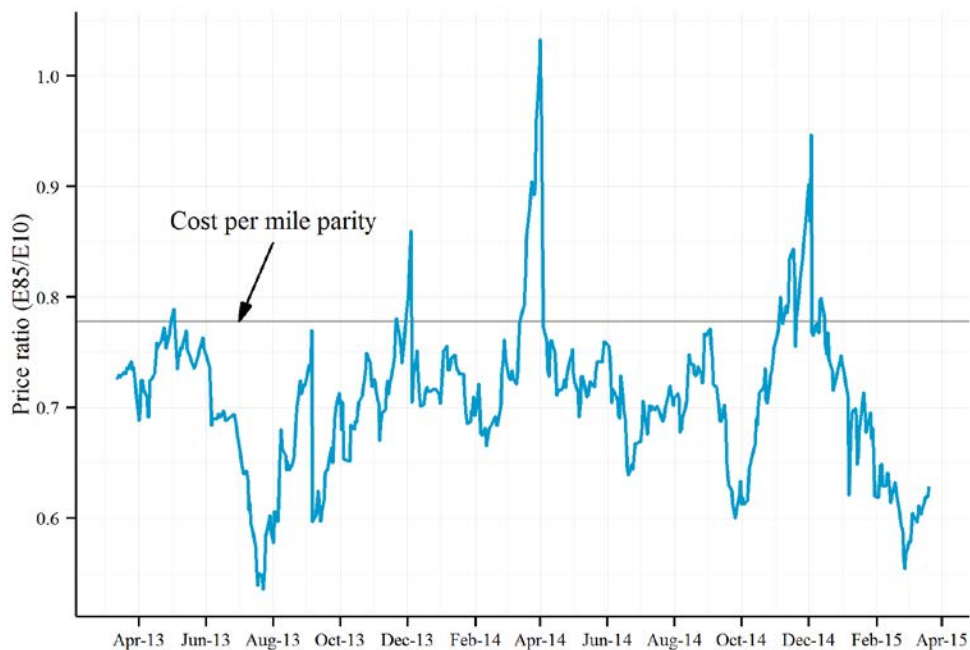


FIGURE 2. Ratio of the wholesale price of E85 and E10

Owners of oil refineries are obligated to meet the blending targets of the Renewable Fuel Standard. They have a financial incentive to see more ethanol sold as E85 because that will generate the RINs that they need for compliance. Of course, the same companies also have a financial incentive to see less E85 sold because higher E85 sales cuts sales of traditional gasoline. Retailers have an incentive to sell more fuel and drive traffic to their stations. If E85 is attractively priced, then this makes them more willing to sell the fuel. Blenders have a financial incentive to sell the RIN and then not discount the price of ethanol in their blends if they can get away with it, which occurs when there is insufficient competition in the ethanol market. Thus, there needs to be sufficient competition among blenders to ensure that a large proportion of the RIN price is reflected in the wholesale price of E85.

It is clear that the pump price of E85 in many parts of the country has not always reflected RIN prices. However, the retail chain that cooperated with us was able to price E85 at various times at retail prices that did reflect RIN prices. Figure 3 shows the average weekly price ratio of E85 to the price of E10 across the retailer's stations in one major Midwest metro area from 2011 to 2014. The large variation in the price ratio at the pump during this time is what is needed to estimate how owners of FFVs respond to E85 price changes.

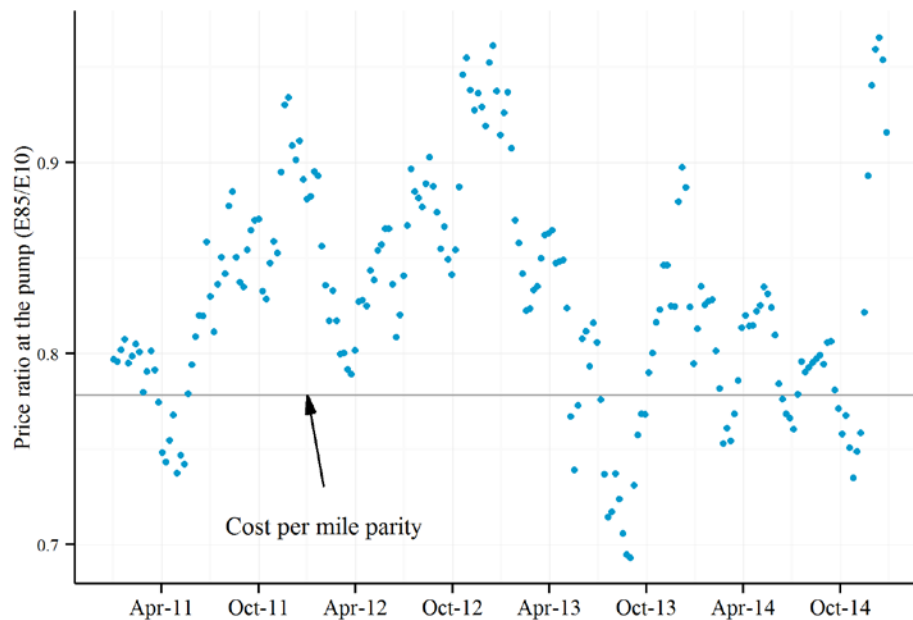


FIGURE 3. Weekly price of E85 relative to E10 price in a major midwest metro market from 2011 to 2014

Estimating Market Penetration of E85

A key factor that determines the amount of ethanol that can be consumed by FFVs is the proportion of FFV owners who choose to run their vehicles on E85 instead of E10. It seems reasonable to assume that a lower E85 price will induce a greater proportion of owners to use E85. The difficulty with estimating market penetration is that the price of E85 is not typically uniform across the country or even in a region. Some owners of FFVs have access to low-priced E85 whereas others do not. It is difficult to derive a meaningful measure of what price to use to measure consumption response in a region when some stations price E85 at cost-per-mile parity while others price it at cost-per-gallon parity.

Our data allows us to avoid this problem because the retailer that provided us data owned nearly all the stations that sold E85 in two metro areas. Furthermore, the retailer charged a uniform price for E85 at all the stations within each metro area. Thus we have data that shows the response of all drivers of FFVs in two metro areas to various E85 prices. We estimate how many FFVs are driven in these metro areas by identifying all the zip codes in the metro areas and then adding up all the FFVs in each of the zip codes. Of course, some of these FFVs will fill up outside their metro area and FFVs from outside the area will fill up inside the metro area. We have no data that allows us to control for these movements so we simply assume that they cancel out.

We have data on the aggregate amount of E85 sold in the two metro areas on a weekly basis, but we have no data on the total volume of fuel consumed per week by owners of FFVs. We estimate the total amount of fuel sold to these vehicles by assuming each FFV would use 10 gallons of E85 per week. This translates to 520 gallons of fuel per year, which, with a 20 mpg vehicle, means that each vehicle is driven 10,400 miles per year. With this assumption, we can then estimate market penetration by dividing the observed level of E85 consumption by the upper limit of E85 that could be consumed by all the FFV motorists in the two metro areas. Figure 4 presents the weekly data.

The effect of lower prices on E85 consumption is apparent in the data. In metro area 1, the relationship is approximately linear for relative prices above the cost-per-mile parity line. For each 5 percentage point drop in the relative price of E85, market penetration increases by approximately 2.5 percent. When the relative price drops below parity, however, market share appears to become more responsive to price. A greater response makes sense because once E85

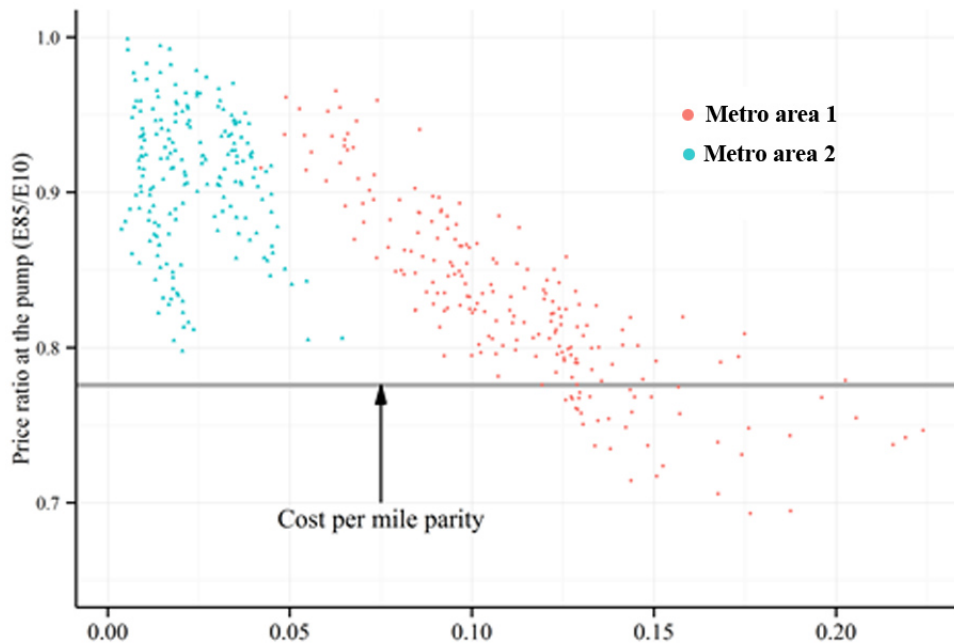


FIGURE 4. Market penetration of E85 in one midwest metro area

is priced low enough to save drivers money, low E85 prices will catch the attention of FFV owners who might not normally consider filling up with E85. In metro area 2, the relationship between relative prices and E85 market penetration is less obvious. One reason is that E85 prices are much higher in area 2, never falling below cost-per-mile parity in the metro area. A second reason is that the number of E85 pumps in metro area 2 has increased over time, causing an outward shift in the consumption of E85 over time, a shift that is evident in Figure 4.

We can establish the relationship between the number of fuel stations and market penetration (measured by E85 market share) using a simple regression model. One nonlinear functional form that can be fit to the data is a power function whereby the natural log of market share is linear in the natural log of the relative price, the natural log of the number of FFV per E85 station and a dummy variable for the metropolitan area. The regression yields

$$\begin{aligned} \text{Log}(\text{share}) = & 4.68 - 5.68 * \text{Log}(\text{Price ratio}) - 1.04 * \text{Log}(\text{FFV per station}) \\ & + 0.20 * \text{Metro area 2}, \end{aligned} \quad (1)$$

where the intercept, the coefficients for the price ratio and the number of FFVs per station are significant at the 99 percent confidence level and the coefficient for the dummy for metro area 2

is significant at a 95 percent level. The regression says that the consumption share is proportional to the concentration of FFVs, such that a one percent increase in the number of FFVs per station causes a 1.04 percent drop in consumption share. This result has two implications: (1) new owners of FFVs have the same preference for E85 as existing owners; and (2) historically the addition of a new E85 pump has caused new consumption of E85 without negatively affecting E85 consumption at previously existing E85 pumps. It is also interesting to note that after controlling for the price of E85 and the number of FFVs per station, the demand for E85 in metro area 2 is 20 percent greater than in metro area 1. This is notable because metro area 1 is located in a Corn Belt state that produces a lot of ethanol and metro area 2 is located in a state that produces no ethanol but a lot of oil and natural gas.

The predicted market shares of E85 in the two metro areas are 28.5 percent in metro area 1 and 12.0 percent in metro area 2 when the number of FFVs per E85 fuel station is at each area's observed values at the end of December 2014 and the relative price of E85 equals 0.7 in both areas. Extrapolating a bit outside the range of the actual data, the predicted market share using this function reaches 43.5 percent in metro area 1 and 18.3 percent in metro area 2 when the pump price of E85 is 65 percent of the pump price of E10. At this pump price the cost per mile of driving with E85 is about 17 percent less than with E10. With this magnitude of cost savings, it seems that 43.5 percent and 18.3 percent market shares are likely lower than what would actually occur if E85 were as widely available as E10. The 18.3 percent predicted market share among FFV motorists in area 2 with a 35 percent discount on E85 reflects the lack of easy availability of E85.

The regression above allows us to extrapolate our findings for these two metro areas to all US metro areas with respect to the concentration of FFVs per E85 fuel stations and the ratio of E85 and E10 prices.

Extrapolation of Results to the National Level

If E85 achieved a 30 percent market share nationally among FFV motorists, then that is equivalent to 5.4 million of the 17.9 million FFVs filling up on E85. At 520 gallons per year, this would mean that 2.1 billion gallons of ethanol would be consumed in E85, which is far greater than needed to meet expanded ethanol mandates. However, such consumption is not possible without increasing the number of stations that sell E85. The two metro areas examined here

respectively contain 41,000 and 46,000 FFVs, which together account for about 0.5 percent of the national total. However, these two metro areas together have 0.8 percent of the nation's E85 stations. In metro areas 1 and 2, there is one fuel station that offers E85 for about 2,070 and 5,750 FFVs, respectively, at the end of 2014.

To extrapolate our findings from these two metropolitan areas, we identified zip codes with a population per square mile that is at least as large as the minimum population per square mile of the zip codes in metro area 1. The rationale for choosing these zip codes is that limiting our extrapolation to urban areas is more justified than extrapolating to both urban and rural areas. Figure 5 shows a map of the zip codes selected. It includes major US cities and suburbs including both metro areas that we studied. Comparing Figures 1 and 5, observe that densely populated areas are those with the most FFVs.

In the selected metropolitan areas there are a total of 9.65 million FFVs and a total of 1,534 fuel stations offering E85, for a concentration of 6,300 FFVs per E85 fuel station. Based on the regression in (1) we can derive the demand for E85 in these selected metro areas. We do this based on the demand for E85 in metro area 1, which we believe provides a more conservative

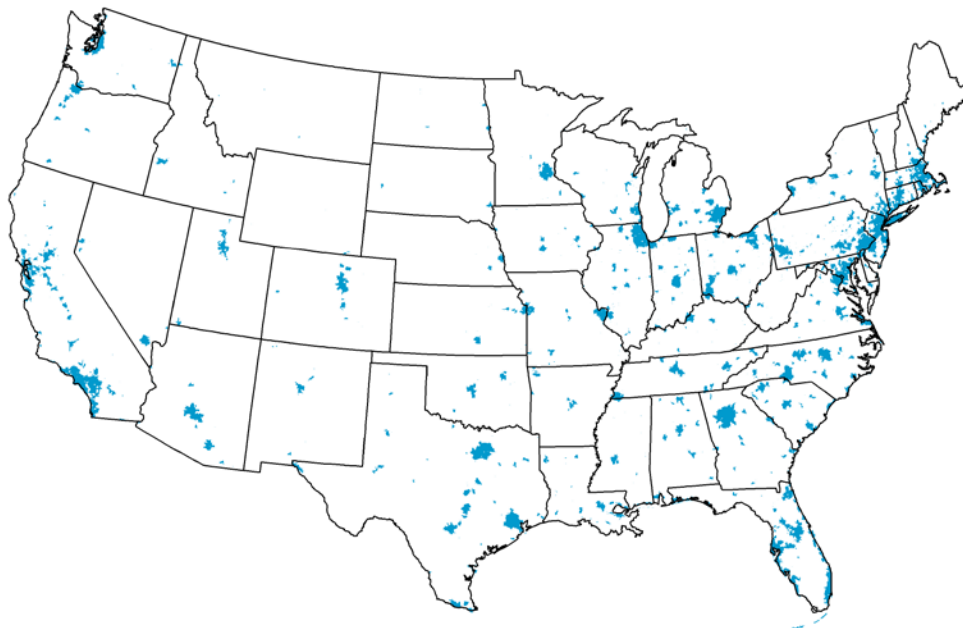


FIGURE 5. Selected metropolitan areas

description of the demand for E85. Recall that demand in area 2 is estimated to be 20 percent higher than demand in area 1. Thus, the demand of E85 we derive assumes nationally that consumers have preferences for E85 similar to those in metro area 1. The blue line in Figure 1 shows the estimated demand for E85 given a concentration of 6,300 FFVs per fuel station—as observed on average in US metropolitan areas. We derived that demand again, assuming that the average motorist consumes 10 gallons of gasoline per week. At price parity, the consumption of E85 is about 250 million gallons. The consumption of 1 billion gallons of E85 in US metro areas requires a price ratio of 0.60. Note that additional consumption of ethanol from the 8 million FFVs located outside US metro areas is not included in these consumption estimates.

To match the concentration of stations in metro area 1 would require an additional 3,128 E85 stations strategically located in US metro areas. The orange line in Figure 6 shows the demand for E85 if this investment were to occur. The difference between the blue and the orange lines represents new consumption because of easier access to E85. The more E85 pumps, the less costly it is for motorists to fuel with E85.

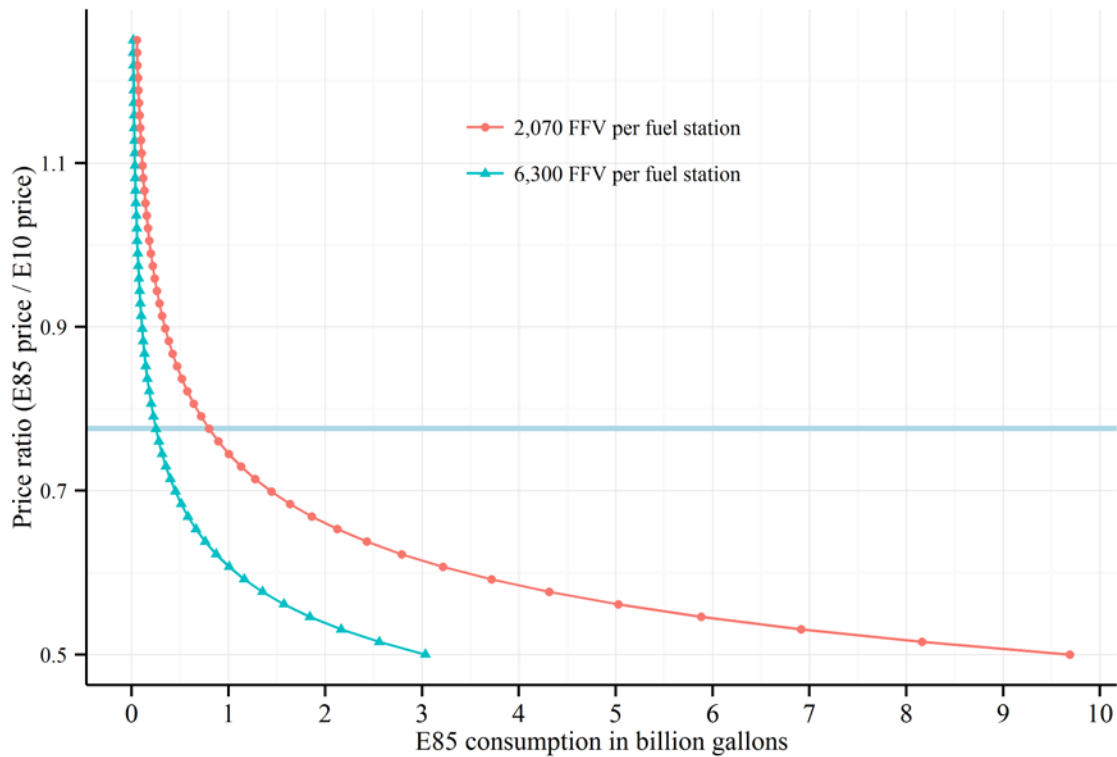


FIGURE 6. Estimated demand for E85 in selected metropolitan areas

With new E85 pumps installed, a price ratio of 0.74 is sufficient to generate the consumption of 1 billion gallons of E85 containing 750 million gallons of ethanol. With a relative price of E85 equal to 0.7, the consumption of E85 increases to about 1.35 billion gallons. With a lower relative price of E85 the quantity demanded increases rapidly as motorists switch from E10 to E85.

The demand curves in Figure 6 are of course not representative of the demand for E85 in the entire United States because it considers only metropolitan areas. Thus, they significantly underestimate the total demand for E85. The demand curves however show the potential for significant consumption of E85 when discounted with respect to regular gasoline.

Policy Implications

The decision by EPA to propose to reduce RFS ethanol mandates on the basis that consumer demand for ethanol is insufficient to meet a 15 billion gallon target seems to be based on EPA believing that owners of FFVS will not switch to E85 if it is attractively priced to save them money and/or that there is insufficient incentive in the market-based RIN trading system to facilitate expansion in the number of stations that sell E85. Our analysis here, based on newly available data, shows that a significant proportion of FFV owners will buy E85 if it is priced to save them money on a cost-per-mile basis. In one metro area that has one E85 station for every 2,070 FFVs, the market share of E85 exceeded 15 percent when E85 saved FFV owners money. Using these new data to estimate a functional relationship between the relative price of E85 and market share, we predict a market share of greater than 40 percent when the price of E85 relative to E10 drops to 0.65. This same function shows that increasing the number of E85 stations significantly increases E85 sales. If investment in sufficient E85 stations in all US metro areas were accomplished to match the ratio of one E85 station per 2,070 FFVs found in one of our study areas, then we estimate that more than enough ethanol would be sold in E85 to meet expanded ethanol mandates in metro areas if the pump price of E85 were 70 percent of the price of E10. Additional large amounts of ethanol would also be sold in rural areas. We calculate that it would take investment in more than 3,000 new metro E85 pumps to accomplish this ratio of E85 stations to FFVs in all metro areas.

Our finding that owners of FFVs like to save money on their fuel purchases is not too surprising: all of us do. Perhaps what is surprising is that EPA's proposed decision to cut ethanol

mandates reveals so little faith in their own compliance mechanism—the RIN trading system. EPA knows that the way to get lower E85 prices is to have a high RIN price. High RIN prices come about with biofuel targets that are more difficult to meet. Because the price of RIN's represents a tax on gasoline production that is sold domestically, a lower RIN price lowers the tax on gasoline producers. Thus, gasoline producers have an incentive to increase the supply of RINs to lower its price. One low-cost way of increasing the supply of RINs is to expand the consumption of E85. EPA set up the RIN trading system to create the incentive to invest in the infrastructure that is needed to expand the consumption of biofuels which, in turn, lowers RIN price. Using the power of the marketplace has proved to be an efficient method of achieving policy objectives.

However, gasoline producers chose to try to reduce RIN prices and their RFS compliance costs not by increasing the supply of RINs but rather by reducing the demand for RINs. A reduction in the demand for RINs can be accomplished by convincing EPA to lower biofuel mandates. If the proposed reduction in biofuel targets is finalized by EPA, then the strategy of gasoline producers to invest in lobbying efforts to lower RIN demand by lowering biofuel mandates will have proved successful. Such success would be disheartening to those who believe that one role of government is to agree on policy objectives and then use efficient market mechanisms to achieve the objectives. Consistency in policy is needed to get regulated industry to make the investments needed to be able to comply with the policy. A rollback of biofuel mandates would demonstrate to future regulated industries that instead of using their resources to lower the cost of meeting regulations, they could instead use their resources to lobby for a reduction in the stringency of the regulations.