Can the U.S. Congressional Ethanol Mandate be Met?

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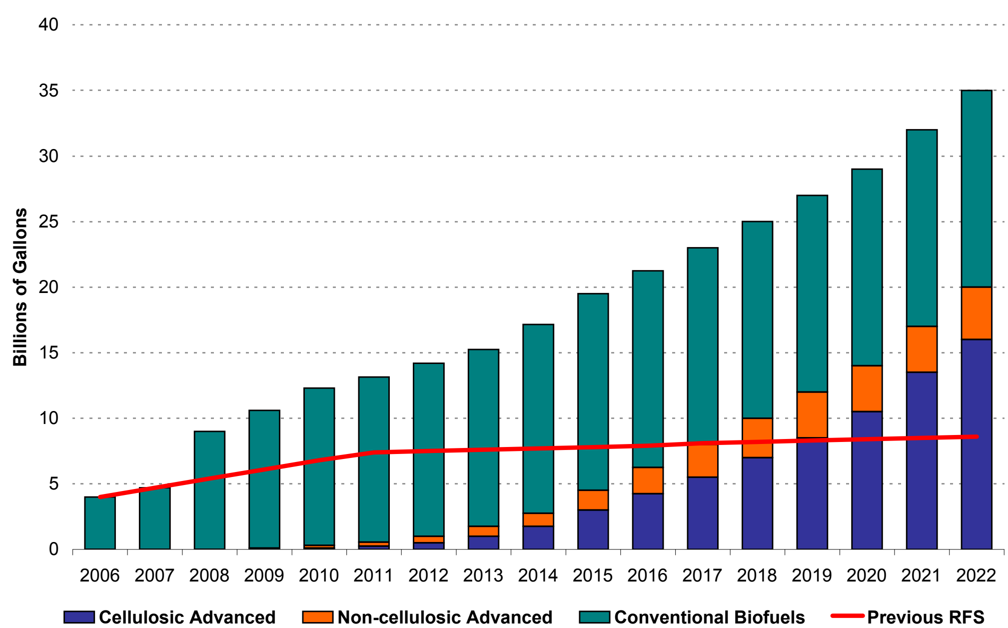
In the Energy Independence and Security Act (EISA) of 2007, the U.S. Congress set an ambitious roadmap for increasing the usage of ethanol in motor vehicle fuel, with mandate levels reaching above 25 percent of projected motor vehicle fuel usage in 2022. The Act spearheaded a shift in focus from corn to cellulosic ethanol, which will require an investment of $50 billion in cellulosic production over the life of the mandate and an additional $12 billion in distribution infrastructure. If this is the objective, regulators and lawmakers must renew their commitment to ethanol and enforce the legislated mandate in order to encourage the necessary investment.

The more complicated issues lie on the demand side, which will require a significant increase in E85 (85 percent ethanol by volume) usage. We project that if cellulosic production costs continue to decrease and achieve similar reductions as corn ethanol has in the past two decades, then ethanol could be cost competitive as early as 2013. Making ethanol work as a major component of our fuel supply will require a concentrated and resolute effort by the government, investors, and manufacturers.

Figure 1 Renewable Fuel Standard (RFS2) 2006 - 2022



Introduction

The United States' transportation energy infrastructure is at an important crossroads. The 2007 mandate by Congress to migrate fuel consumption from traditional gasoline to biofuel requires that significant steps be taken to update the automotive fleet and the way we produce and distribute fuel. However, serious questions remain on both the demand side and supply side of the equation: can we produce and consume as much ethanol as Congress has mandated? And if we can, will producers be able to sell ethanol profitably without government subsidies? This paper discusses potential demand side and supply side impediments in meeting the mandate, and analyzes the prospects for profitably producing ethanol in the next decade.

Currently, the U.S. has neither the proper automotive fleet necessary to consume the mandated 35 billion gallons of non-diesel ethanol,[1] nor the renewable fuel technology to meet the final production requirements. And yet in the near future, the required levels of ethanol can be produced and consumed.

In the longer run, economic problems in meeting the mandate will emerge, largely because the 35 billion gallons of non-diesel ethanol includes not only 15 billion gallons of corn ethanol, but also 20 billion gallons of non-corn-based advanced biofuel, which must be blended into our fuel supply in 2022. Because today's capacity to produce the latter fuel is negligible, there are both technological and economic issues that need to be addressed immediately.

In the near term, we should expect to see a move by refiners towards increased production of universal E10 (a blend of 10 percent ethanol and 90 percent gasoline),[2] in order to saturate this available market. However, additional ethanol consumption in the conventional market would require that the U.S. Environmental Protection Agency (EPA) or Congress raise the allowed ethanol content. The other means for significant increase in consumption is through increased usage of E85, an ethanol blend used almost exclusively in flex-fuel vehicles (FFVs). This requires increasing the refueling rate of the existing fleet of eight million FFVs and their numbers on the road. The major hurdles to increased FFV utilization are:

- *addressing the price disparity between ethanol and gasoline, which could be accomplished through natural market mechanisms once E85 consumption reaches a critical mass;*
- *ensuring that there are enough service stations capable of dispensing E85, which, due to the expense of conversion or construction, will need be accomplished via government incentive programs.*

On the supply side, for there to be any reasonable likelihood of meeting the ethanol mandate on schedule, there must be significant progress made by 2012 to build commercial-scale cellulosic ethanol manufacturing facilities. While the technology for corn-based ethanol is mature, the technology for producing alternative biofuel is inchoate, with less than five million gallons of existing capacity and just 1.4 billion gallons of new biofuel capacity in the pipeline.[3] Assuming that technical innovations are made rapidly, meeting the cellulosic mandate by 2022 will require approximately $66 billion of investment; $50 billion for the development of commercial-scale cellulosic ethanol facilities, $12 billion for new distribution infrastructure, and $4 billion for corn ethanol.

Even if the U.S. can theoretically produce and consume 35 billion gallons of ethanol in 2022, will it actually be economically viable to do so? If the costs of producing cellulosic ethanol exhibit reductions consistent with those achieved in the production of corn ethanol (and corn ethanol production continues its innovation over the next 10 years), then with current projections of gasoline prices the mandated ethanol will be cost competitive with gasoline by 2013.

The next year will be crucial in determining the future for ethanol standards. In February 2010, the EPA chose to reduce the cellulosic ethanol mandate set by Congress for 2010 from 100 million gallons to 6.5 million gallons. It is improbable that suppliers would have been able to meet the initial standard mandated by Congress. However, this leaves us in a precarious situation going forward. If investors believe that the EPA will continue to lower ethanol mandates for future years, there is little incentive to invest in the industry. That said, policy-makers are claiming that "a number of companies and projects appear to be poised to expand production over the next several years,"[4] and hope this momentum will put us back on track to meet the cellulosic mandate in future years. The next year will show how policy-makers and investors handle this catch-22 situation.

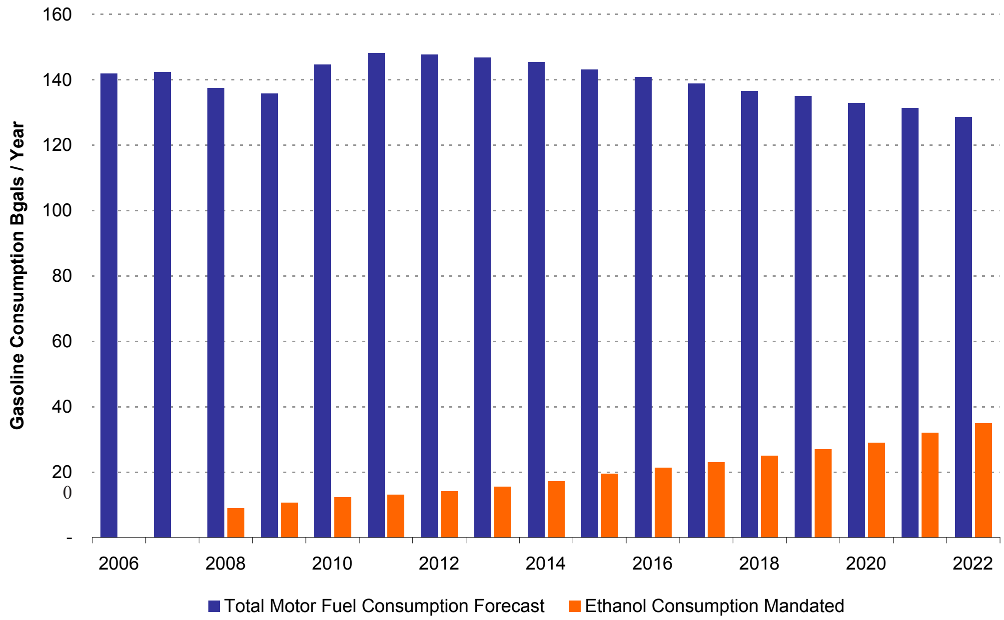
Section 1 of this paper is a review of the current renewable fuel standard. Section 2 focuses on the demand side, and looks at the two key steps we can take to consume the mandated fuel and the long-term step of incorporating 21 million new FFVs. Section 3 focuses on the supply side, looking at the prospects for increasing the production of cellulosic ethanol as well as the ability of auto manufacturers to ramp up production of FFVs. Finally, Section 4 analyzes the prospects for ethanol and cellulosic ethanol achieving economic viability in the next decade.

Section 1 THE CURRENT RENEWABLE FUEL STANDARD

As a result of two recent acts of Congress, the U.S. is planning a large expansion of renewable fuels over the next 15 years. The first of these is the Energy Policy Act of 2005 (2005 Act),[5] which brought about the concept of Renewable Identification Numbers (RINs) and a Renewable Fuel Standard (RFS). These were key pieces of a plan to double the production of ethanol-based renewable fuels by 2014 (RFS1). The second was the EISA, which superseded the 2005 Act by imposing higher standards on the amount of renewable fuel blended into gasoline, jet fuel,[6] diesel, and other transportation fuels in the U.S. annually through 2022 (RFS2). This standard goes further than just requiring more ethanol production; it requires different types of ethanol production such as cellulosic ethanol and biodiesel.[7]

As shown in Figure 2, RFS2 will require the blending of 35 billion gallons of non-diesel renewable fuel by year 2022,[8] a quadrupling of the 9.2 billion gallons of renewable fuel consumed in 2008[9] and over 25 percent of the total projected motor vehicle fuel usage in 2022.

Figure 2 Energy Information Administration (EIA) Forecast and Renewable Fuel Mandates



The RFS2 non-diesel ethanol quotas from the EISA are broken down into three individual mandates:[10]

1. *Renewable biofuel – ethanol derived from corn starch, which achieves at least a 20 percent greenhouse gas (GHG) reduction compared to the 2005 baseline lifecycle emissions.*[11]
2. *Cellulosic – ethanol derived from specific renewable biomass, which achieves at least a 60 percent GHG reduction.*
3. *Any advanced biofuel – cellulosic, biodiesel, and any other non-corn source that achieves at least the 50 percent GHG reduction. For example, cellulosic ethanol, which achieves a 50 percent GHG reduction, would not qualify as cellulosic but would qualify as an advanced biofuel.*

The EISA breaks out specific amounts of each of the three types of fuel to be blended in with the fuel supply from 2008 through 2022. Figure 1 shows the RFS2 standards that fuel producers and importers need to comply with through RINs trading. Note that in 2008, nine billion gallons of biofuel were required to be blended into the fuel supply, all of which could be from corn starch. In 2010, 6.5 million gallons of cellulosic ethanol are required to be blended, ramping up to 16 billion gallons in 2022. As the current commercial capacity is negligible, this portends the challenge for the industry.

Section 2 DEMAND SIDE

On the demand side, there are three simple steps that will get us more than halfway to the RFS2 consumption goal. The first and simplest step is to deploy E10 to every possible gas station in the U.S. This should occur naturally as the mandate for ethanol increases over time, and should result in an additional 3.1 billion gallons of annual ethanol consumption. The second step is raising the maximum allowable ethanol content for conventional fuel from 10 percent to at least 12 percent (E12), which can likely be absorbed into the current vehicle fleet with little new innovation or investment. Finally, raising the refueling rate of the 8 million FFVs currently in service would increase total consumption to about 21.7 billion gallons of ethanol.

However, as Table 1 shows, these changes would still leave an annual consumption shortfall of about 13 billion gallons of ethanol. In order to consume this additional renewable fuel, the most obvious current option is increasing the FFV fleet from 8 million vehicles today to at least 29 million new vehicles in service by 2022. This will also require the addition of thousands of new distribution points for E85 fuel. Short of converting our entire automobile fleet to biodiesel in the next decade, there is little, if any, chance of meeting the ethanol mandate in the renewable fuel standard without focusing on consumption of higher quantities of ethanol, such as E85.

Table 1 The Road to 35 Billion Gallons[12]

Current usage	10.7 billion gallons
Move to universal E10	3.1 billion gallons
Move to E12	2.8 billion gallons
Raise refuel rate of existing FFVs to 70%	5.1 billion gallons
Increase the number of FFVs by 21 million	13.3 billion gallons
Total renewable fuel consumption	**35.0 billion gallons**

2.1 Make E10 Universally Available

Virtually every vehicle on the road today can use fuel with up to 10 percent ethanol by volume, known as E10, without an impact on operability.[13] Currently, the nationwide average for ethanol blended into motor fuels (in gasoline) is around 7.75 percent.[14] Universal E10 can be incorporated without major changes to existing distribution or transportation infrastructure since the blended E10 grade fuel can be shipped through ordinary methods and dispensed and used in ordinary vehicle tanks.[15] Thus, a first step to increasing renewable fuel consumption in the U.S. would be making E10 universally available. This change alone would allow an increase in renewable fuel consumption to approximately 13.8 billion gallons.[16]

E10 is also known as the "blend wall," since a Clean Air Act waiver from 1978 limits the amount of ethanol that can be blended into gasoline at 10 percent.[17] Under RFS2 quotas, this means that we will hit the blend wall in approximately 2012, as the 15.2 billion gallons of renewable fuel that are required by 2012 will saturate the fuel stock with 10 percent ethanol.[18]

2.2 Raise the Blend Wall From E10 to E12

While E10 is compatible with virtually every vehicle on the road today, some are questioning if the ethanol content could be increased to utilize E12,[19] E15, or E20 without harm.[20] Currently there are studies under way examining the use of these fuels in conventional vehicles to gauge the impact on operability. These preliminary results give hope that the current vehicle fleet could absorb a significantly higher share of the ethanol mandated by RFS2.[21] Although Congress chose to pass on raising the blend wall at the end of 2009, it will be revisiting the issue in May 2010 when additional research is available.

Should blends of E12, E15, or E20 be approved for conventional use, the blend wall would move to over 16 billion gallons in the case of E12, 21 billion gallons in the case of E15, and around 28 billion gallons in the case of E20. This would put the dates where we *hit* the blend wall at around 2013, 2016, or 2020, respectively.[22] In addition, if the Clean Air Act were amended to allow these blends, the respective amounts of fuel could be absorbed right away by the vehicle fleet, which would mitigate the urgency to find other consumption mechanisms for ethanol (most notably E85, discussed below).

2.3 Increase the Refueling Rate of E85 for Existing FFVs

Looking beyond E10, FFV owners currently have the ability to consume E85.[23] These are vehicles with special engines that can consume conventional gasoline and ethanol blends up to E85. If the Clean Air Act is not changed to allow E12, E15, or E20, then most if not all of the ethanol produced above the blend wall would need to be blended into E85.

At present there are approximately eight million FFVs on the road,[24] three percent of the 225 million vehicles in the U.S. fleet.[25] These eight million FFVs have the capacity to consume almost seven billion gallons of E85 per year.[26] However, in 2008 FFV owners only tapped in to an average of 0.2 percent of their vehicles' ethanol usage potential. Assuming only four percent of the nation had reasonable access to E85 refueling stations, this equates to a five percent refueling rate for those with access.[27]

There are two reasons for the low refueling rate of FFVs. First, there is a general "chicken and egg" problem, where the density of FFVs is not high enough to warrant E85 fueling stations, which limits the appeal of consumers purchasing and using them. Second, approximately 1.4 gallons of E85 are required to produce the same amount of energy as a gallon of gasoline. Table 2 illustrates the relative efficiency issue. It lists the energy content per gallon for pure gasoline, ethanol, and various blends, along with the equivalencies for the energy in the blends to match up with the energy in one gallon of pure gasoline.

Table 2 Energy of Fuels and Equivalencies to Gasoline[28]

Fuel Type	Energy BTU/gal	Amount needed for equal energy to 1 unit of gasoline
Gasoline	115,000	1.000
Ethanol	75,700	1.519
E10	111,070	1.035
E15	109,105	1.054
E20	107,140	1.073
E85	81,595	1.409

Table 2 shows that there is a substantial decrease in efficiency as more and more ethanol is blended into fuel supplies, lowering fuel economy in vehicles and increasing the total amount of fuel needed for a given number of miles traveled. For blends up to E10, the change is marginal and likely not noticeable to average consumers (and, indeed, they are never certain what level from E0 to E10 they are getting at most commercial pumps). For E85, however, the energy difference is approximately 30 percent lower than that of pure gasoline. A comparison of all the 2010 model year FFVs shows that the drop in fuel economy ranges from 23 to 36 percent, with an average of 27 percent.[29] Thus E85 should be at least 27 percent less expensive than pure gasoline to make a driver indifferent between the two.[30] Of course, FFVs are able to accommodate fuel mixes from E0 to E85, which means that unless consumers can be sure of the tradeoff between energy content and price differentials, they are likely to continue refueling with the traditional fuel blends.

However, according to a June 2009 price report from an independent online tracker of E85 prices,[31] the average price differential was 17.9 percent with predictions for it to stay roughly constant for the short term between 16 and 20 percent. Only the state of Massachusetts had a difference of more than 27 percent. Making ethanol economically attractive relative to motor gasoline is critical if we hope to raise the E85 refueling rate.

If the refueling rate were 100 percent, this would raise the blend wall in a combined E85/E10 world to over 21 billion gallons. Under this scenario, the potential for compliance with RFS2 using the current U.S. fleet and infrastructure would be pushed back until 2016. When combined with projections on E85 refueling stations (see Section 4), a more realistic refueling rate of 70 percent would allow for 5.1 billion additional gallons of renewable fuel consumption, pushing the blend wall out to 2015.

2.4 Increase the Number of E85 Refueling Stations

It is predicted that 28,750 new refueling stations will be needed by 2022 to raise the nationwide E85 refueling rate to 70 percent.[32] At present, of the approximately 160,000 commercial refueling stations in the U.S., only 1,800 offer E85 – barely more than one percent.[33] Additionally, the 28,750 number assumes that stations are placed efficiently to allow maximum access. While we offer no opinion if that is a reasonable assumption, that number of stations should be taken as a minimum since any inefficient placement would require additional E85 stations to provide uniform access.

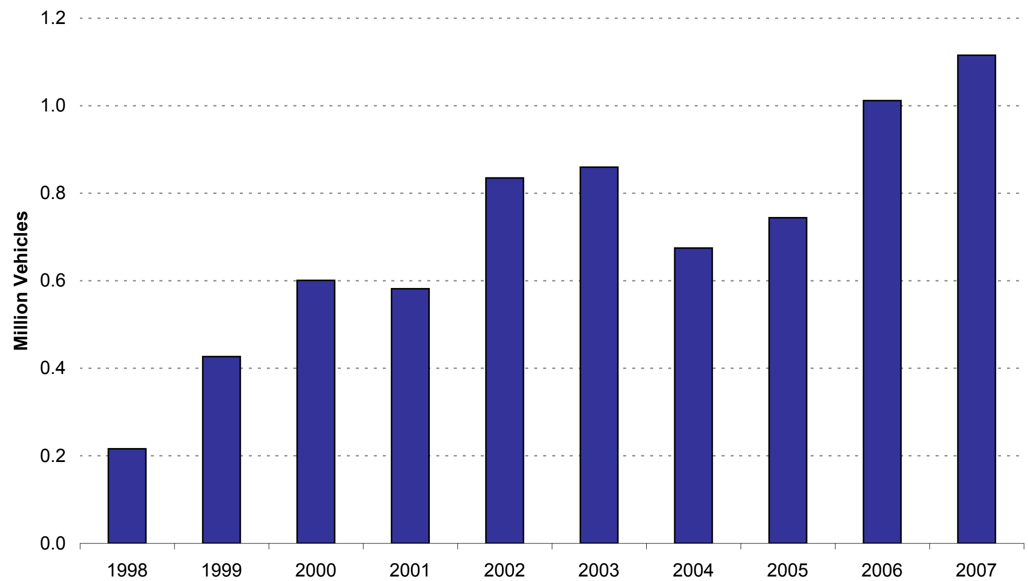
Unlike traditional fueling stations that can easily utilize E10, E85 requires special tanks and pumps to preserve the high blend of ethanol. According to a study done in the Texas/Oklahoma market, upgrading part of a system installed in 2007 to service E85 would cost at least $11,000. Replacing an entire system can be substantially more than $150,000 per facility. The implementation of a sufficient number of upgrades looks particularly unlikely since most fuel retail/convenience stores operate as single-store companies. Also, in 2007 the average convenience/petroleum retailer reported a pre-tax profit of $23,335.[34]

The question then is how to increase the number of stations, given that low profits earned at fueling stations provide insubstantial capital for E85 infrastructure investments. The EISA does contain provisions to establish a grant to E85 infrastructure costs. However, with the likely need for a 2010 federal economic stimulus, grants, perhaps combined with accelerated depreciation on leases for E85 infrastructure, may assist in achieving the fuel mandates in the short run. Given the existing FFV stock and the potential for achieving sufficient network densities, such incentives could be the most economically viable of short-run policies targeted to meeting the fuel mandates. These incentives take advantage of making the most efficient use of the existing underutilized FFV investments.

2.5 Incorporate More FFVs into the Vehicle Fleet

For the full mandate to be met, it will still be necessary for an additional 21 million FFVs to be put into service between now and 2022. A number of manufacturers in the U.S. have been offering FFV versions of their models since the late 1990s. During the last five years, FFV models were offered by Chevrolet, Dodge, Nissan, and Toyota, among others.[35] As shown in Figure 3, based on data from the U.S. Department of Energy (DOE),[36] the number of FFVs sold in the U.S. increased from about 200,000 vehicles in 1998 to a little over one million vehicles in 2007. Compared to an annual average of roughly 15 million light-duty vehicles sold in the U.S., FFVs still constitute only a small fraction of the historical sales.

Figure 3 Annual Sales of FFVs in the U.S.



Source: Energy Information Administration, Form EIA-886, "Annual Survey of Alternative Fuel Vehicle Suppliers and Users," as reported in "Alternatives to Traditional Transportation Fuels," 1998-2005 reports (Table 14 or S1, depending on year of report).

Based on the most recent projections by the DOE,[37] the stock of FFVs (cars and light trucks) will increase from about 8 million now to 20 million in 2015 and 34 million in 2020. This increase of 25 million in FFV stock over the next 10 years corresponds to annual sales of more than 1.5 million FFVs. If these projections are realized, the U.S. can reach the additional 21 million threshold level of FFVs by approximately 2016, making it feasible to consume the mandated 35 billion gallons of non-diesel ethanol by 2022. Whether it will be economic for FFV owners to prefer to use E85 instead of motor gasoline will still be an issue.

In the case of Brazil, subsidized loans to ethanol producers and implementation of price controls on ethanol until the end of the 1980s incentivized the use of an ethanol blend in vehicles. In addition, the current mandatory gasoline blend of E25 and mandatory offering of ethanol in fuel stations resulted in almost all Brazilian fuel stations offering ethanol as of the end of 2006.[38] Brazil's FFV fleet is about nine million, approximately 23 percent of all light-duty vehicles on their roads today.[39]

Section 3 SUPPLY SIDE

In addition to the demand side impediments to the RFS2 mandate compliance discussed above, there are also potential supply side constraints with respect to ethanol production and distribution and the production of FFVs. For cellulosic ethanol, technological innovation is required to increase commercial production levels, and much investment in domestic infrastructure will be necessary to incorporate the new volume of ethanol into our fuel supply. For FFVs, manufacturers have both the ability and the incentive to continue the current trends, which will be necessary to produce the vehicles to consume enough E85 to meet the mandate.

3.1 Increase the Production of Cellulosic Ethanol

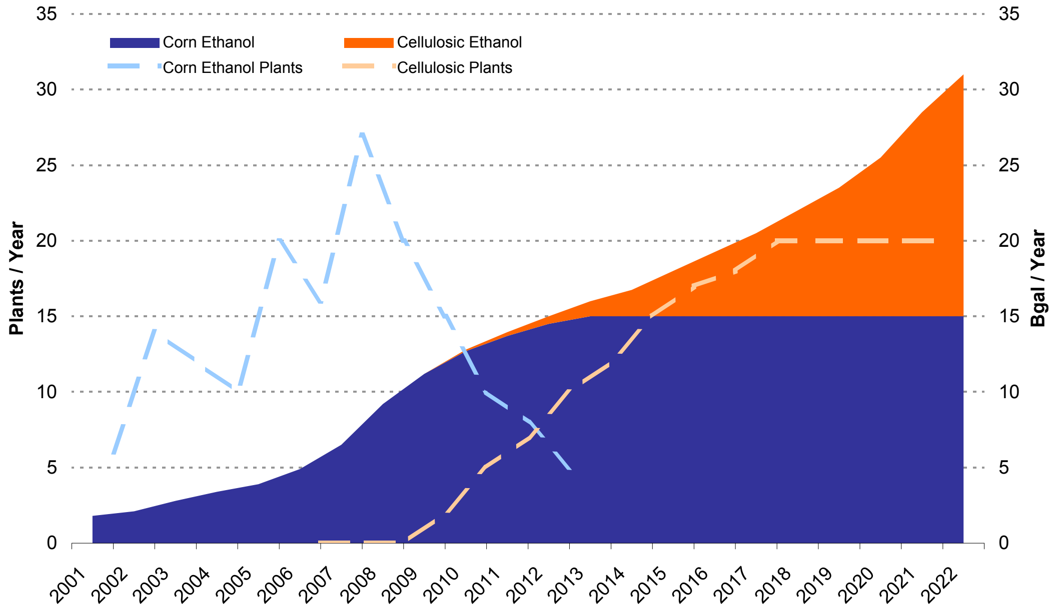
Cellulosic ethanol is a subtype of advanced biofuel that is derived primarily from the non-edible parts of plants or other biomass such as wood or grasses.[40] Cellulosic ethanol is particularly relevant to this discussion because it is a separate and significant component of RFS2 quotas; at least 16 billion gallons of ethanol are mandated by 2022. In 2008, only 3.17 *million* gallons of cellulosic ethanol were included in the fuel supply. Cellulosic sources of ethanol are destined to be even more important by 2022, since above the 16 billion gallons of cellulosic ethanol required under RFS2, there are some four billion gallons of other advanced biofuel that are required by 2022. While sugar and other known ethanol sources could satisfy this mandate, there is also a strong likelihood that, given the predicted expansion in commercial production of cellulosic ethanol, this quota will be met from cellulosic sources. This would raise the required production level to 20 billion gallons by 2022.

At present, the commercial capacity of cellulosic ethanol in the U.S. is a few *million* gallons.[41] Due to the financial crisis, we did not see nearly as much growth in production as was expected in 2009. Accordingly, the EPA lowered the cellulosic component of the mandate for 2010. While this change allows the U.S. to meet its cellulosic ethanol requirements in 2010, the requirements under RFS2 are still expected to ramp up in the future, leaving the need for increased capacity in the coming years. Given a lag of up to four years for plant production, it would appear that plans must be laid now if there is to be any hope of meeting the increasing RFS2 quotas in 2011 and beyond.

Currently some 21 plants are under construction with various expected dates of completion. However, the capacity of these plants is small relative to corn ethanol, ranging from annual production levels of 500,000 to 70 million gallons per year. If all of these plants under construction were to come online by 2011, the total annual production level would be 273.1 million gallons – barely over the RFS2 quota for that year.[42]

While the current levels of cellulosic ethanol production are low, both the EPA and Sandia National Laboratories believe production of at least 20 billion gallons by year 2022 is possible, without displacing current crops.[43] To do this would require a significant sustained build rate of cellulosic ethanol plants from 2010 onwards, totaling some 186 plants coming online between 2010 and 2022.[44] While this may sound like a high rate, as Figure 4 demonstrates, a comparison to corn ethanol production in the last decade provides the basis for some optimism.

Figure 4 Historic and Projected U.S. Ethanol Production Trends 2001-2022



Source: "Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program," U.S. Environmental Protection Agency, EPA420-D-9-001, May 2009, p. 71. Note: Corn capacity is capped at RFS2 maximum of 15 billion gallons per year. Cellulosic production is projected to meet RFS2.

During the period 2002-2006, the average production capacity of new corn ethanol plants was 50 million gallons, which then jumped to 100 million gallons from 2007 onward. While the number of new plants built in 2002 was just 6, in 2008 it was 27.[45] Indeed, as the U.S. gets closer to producing 15 billion gallons of corn ethanol (for which it almost has capacity), the build rate for corn ethanol will likely disappear entirely. Thus it would be reasonable to assume that there would be a number of engineering and construction firms in areas where ethanol production is prevalent (for instance in the Midwest) available to build new cellulosic ethanol plants.

Given that the technology exists now to build a 20 million gallon plant, it is plausible for the plant sizes to increase to 100 million gallons per plant in a time frame similar to that of corn ethanol's expansion. Indeed, one plant under construction today could have a 70 million gallon capacity when finished. While it is certainly too early in both RFS2 and the technological innovation cycle to make definitive predictions, we would expect that our ability to undertake the massive capacity build-out will be driven by the ability of the technology to deliver an economically viable product. Or absent that, for Congress to step in and provide the funding and support necessary to make cellulosic ethanol competitive with both corn ethanol and petroleum.

3.2 Costs of Producing and Distributing Extra Renewable Fuel

The capital investment needed to comply with RFS2 is expected to be approximately $58.3 billion by 2022.[46] As can be seen in Table 3, the expected capital costs related to cellulosic expansion dwarf that of corn ethanol expansion due to the abundance of existing infrastructure for corn.

Table 3 Projected U.S. Capital Costs by 2022 Attributed to Ethanol as a Result of RFS2[47]

Plant Type	Capital Investment (billion $)
Corn Ethanol	4.0
Cellulosic Ethanol	50.1
Ethanol Distribution	12.1
Petroleum Refining	-7.9
TOTAL	**$58.3**

3.3 Plant Costs for Cellulosic Ethanol

The total capital cost for new cellulosic ethanol plants is estimated to be $50.1 billion, with the underlying assumptions that plant costs will decrease slightly from $231.7 million per plant in 2010 to $220.1 million in 2015, and $198.6 million by 2022. An additional assumption is that the average plant size will increase slowly to 71 million gallons production per year in 2022.[48] While this assumption does not quite match up with the increase in plant size predicted earlier, these figures are used as a capital cost estimate based on studies of feedstock availability and basic construction costs.

3.4 Distribution Costs for Ethanol

Distribution of the quantities of ethanol required under RFS2 is a major obstacle to successful implementation. The current location of ethanol producing plants is not aligned with nationwide demand and distribution venues through the existing pipelines.[49] Most current and proposed ethanol plants are in the Midwest, which is not proximate to the origins of existing oil pipelines on the Northeast and Gulf Coasts. At present, feasibility studies are ongoing regarding the construction of a dedicated ethanol pipeline from the Midwest to the East Coast. However, the construction of such a pipeline would require an investment of several billion dollars and questions remain as to whether it would be technically functional. For example, without addressing the problem of the separation during shipment of highly concentrated ethanol-gasoline blends in pipelines due to water vapor,[50] a pipeline would be technically infeasible, as once water is mixed into the blend the gasoline becomes unviable.[51]

As a result of foreseeable problems with shipment via pipeline, it is assumed that the bulk of ethanol will be delivered by rail, tank truck, and barge, as it is now.[52] In 2005, approximately 60 percent of ethanol was transported by rail, 30 percent by tank truck, and 10 percent by barge.[53] Shipping pure ethanol this way to collection tanks for in-line blending with gasoline is relatively simple; it would require minimal expansion at retail facilities, only an expansion in storage tanks and freight vehicles. Given that virtually every vehicle in the U.S. can utilize blends up to E10, there are no foreseeable costs in updating vehicle fuel tanks and engines. The estimated distribution capital costs by the DOE are detailed in Table 4.

Table 4 Estimated Ethanol Distribution Infrastructure Capital Costs[54]

Facilities	Infrastructure Capital Costs (million $)
Fixed Facilities	
Marine Import Facilities	49
Ethanol Receipt Facilities at Rail Terminals	
Rail Car Handling	1,264
Ethanol Storage Tanks	354
Petroleum Terminals	
Rail Receipt Facilities	2,482
Ethanol Storage Tanks	1,611
Ethanol Blending and Miscellaneous Equipment	545
E85 Retail Facilities[55]	2,957
Mobile Facilities	
Rail Cars	2,938
Barges	183
Tank Trucks	223
TOTAL Ethanol Distribution Capital Costs	**$12,066**

It should be noted that all of these distribution infrastructure capital costs do not have any allotment for ancillary costs associated with upgrading the rail, marine, and road transportation facilities to handle the increased freight volume of renewable fuels. There are two reasons for this. First, changes due to RFS2 are predicted to account for only two percent of the total increase in freight tonnage by year 2022; second, it is difficult to estimate these non-direct costs.

3.5 Produce More FFVs

A major expansion of the current FFV fleet will be needed to meet the RFS2 ethanol consumption targets. While perhaps daunting, Brazil's foray into alternative fuels is encouraging as it has quickly resulted in nearly all new vehicle sales being FFVs. Brazil went from 22 percent of all new vehicle sales coming from FFVs in 2004 to 94 percent in August 2009.[56]

After the move to increase the blend wall and incorporate universal E12 in order to meet the RFS2 targets with FFVs, E85 consumption will have to be about 18 billion gallons, or about three times the capacity of the current FFV fleet. Assuming the price gap between regular and E85 fuel continues to widen to make E85 viable relative to gasoline, and that E85 station access improves, 21 million more FFVs will need to be incorporated into the U.S. fleet by 2022 in order to consume 18 billion gallons of E85. While current production trends indicate this level is easily attainable, continued legislative support and government regulation will likely be necessary to ensure such production. However, even without intervention, we would expect continued expansion of FFV production because the cost difference between FFVs and conventional automobiles is negligible – $50 to $100 per vehicle[57] - and the production of FFVs helps automakers reduce their fleet fuel economy requirement.[58] In addition, FFVs can be sold to consumers even if they have no current expectation of refueling with E85.

Alternatively, if the economics of E85 production and distribution is such that the fuel cannot be produced for the long term at a price competitive with conventional gasoline, this could be an indicator that the ethanol mandates as currently legislated are economically unrealistic. As this becomes apparent, regulators or lawmakers will need to revise policies to put economic realities and national goals in line with each other.

Section 4 ECONOMIC VIABILITY OF ETHANOL

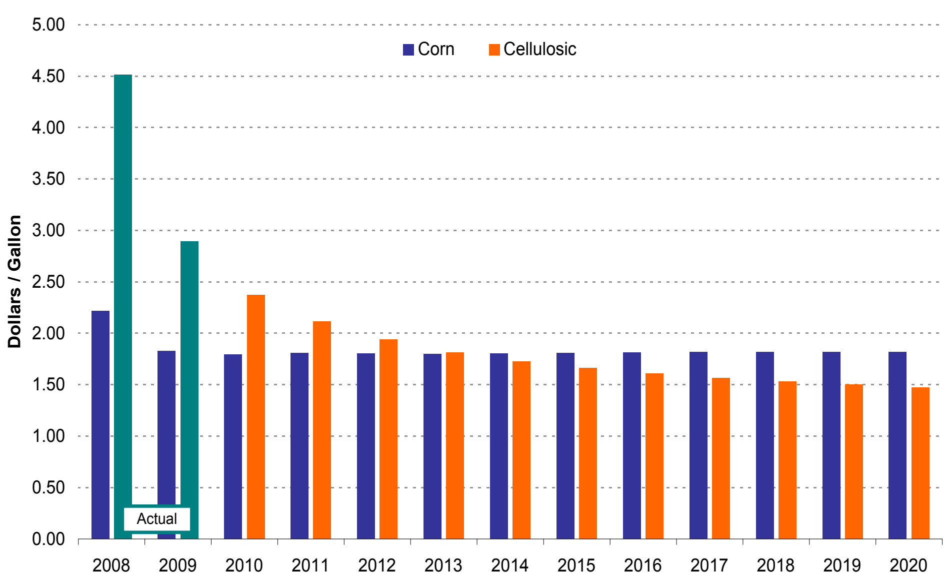
We have discussed the costs of meeting the 35 billion gallons of ethanol and presented the required changes to meet the RFS2 mandate. However, the question of the economic viability of ethanol remains. The only way for long-term viability of ethanol to be possible is if it is priced competitively with its gasoline alternative.

Using the conversion rates in Table 2, we can conclude that pure ethanol needs to be priced at about 35 percent less than conventional gasoline to be a competitive option.[59] This is a rough estimate because it is based purely on the lower energy content and does not take into account efficiencies due to a higher octane rating or additional costs due to extra time spent refueling, etc. However, using this conversion parameter and ethanol production cost forecasts, we have estimated when ethanol could begin to be a viable fuel alternative; or in other words, when we could begin to see ethanol priced competitively against gasoline without government price support.

There are two major components of ethanol cost – production costs and transportation costs. Corn ethanol production costs have decreased by about 60 percent since the early 1980s. Using an experience curve methodology, costs are expected to decrease by another 30 percent in the next 10 years.[60] Currently the U.S. has no commercially operating cellulosic ethanol plants. POET, a leading ethanol producer, has developed a pilot plant in Emmetsburg, Iowa. In the first year alone, POET was able to reduce its production costs from $4.13 per gallon to $2.35 per gallon.[61] Assuming such innovation continues, we will be well on our way to meeting the 2020 cellulosic production cost forecast set by the National Commission on Energy Policy of 80 cents per gallon (before transportation costs).[62]

Transportation costs can be a significant factor for ethanol due to concerns discussed in Section 3 - most importantly, the inability to pipe ethanol from its production centers. The current cost of transporting ethanol from the Midwest states, where most refineries are, to the coastal states is around 60 cents per gallon.[63] We assume 60 cents as the average transportation cost for 2009, and grow it at the annual rate of increase in EIA's forecast of motor gasoline prices going forward. The resulting transportation cost forecast is added on to the estimated production cost to obtain a total cost.

Figure 5 Total Production and Transportation Costs for Ethanol

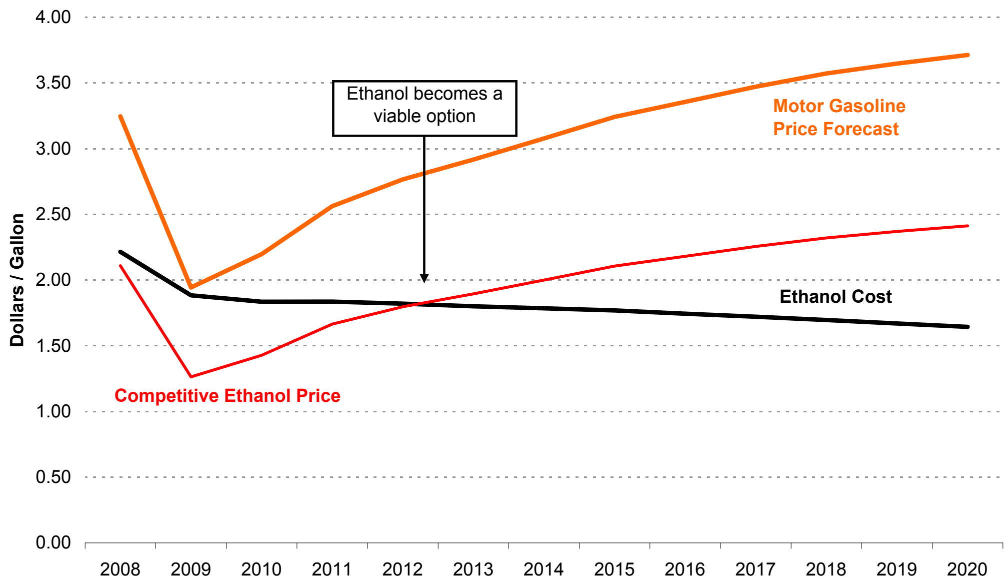


Source: Corn estimates for 2008 and 2020 from Hettinga, W.G., Junginger, H.M., S. C. Dekker, M. Hoogwijk, A.J. Mcaloon, and K.B. Hicks, "Understanding the reductions in US corn ethanol production costs: An experience curve approach," *Energy Policy*, 2009, p. 190-203.

Figure 5 shows the estimated trends in costs of corn and cellulosic ethanol given the assumptions discussed above. Cellulosic ethanol is expected to experience a significant decrease in costs going forward, while corn ethanol costs will be steadier, since most of the innovation is behind us. These estimates assume that investment in technology will continue to grow as planned.

Using these total cost estimates and the quantity of cellulosic and corn ethanol mandated by RFS2 in Figure 6, we determine the average ethanol production and transportation costs up to 2020 without factoring in the current ethanol subsidy of 51 cents per gallon. On the same figure is the EIA forecast for the market price of gasoline, as well as a 35 percent discount to the EIA forecast - the threshold for competitive ethanol pricing. When ethanol costs dip below the 35 percent discount to the EIA gasoline forecast, ethanol is economically viable. This occurs for the first time in 2013.

Figure 6 Ethanol Costs vs. Competitive Pricing



Source and Notes: "Motor Gasoline Price Forecast" from U.S. Energy Information Administration, AEO2009 Updated Reference Case. Ethanol costs are an average of cellulosic and corn ethanol production and transportation costs, weighted by the proportions mandated for each year.

There are a number of simplifying assumptions built into this calculation that should be discussed. Most importantly, note that we are comparing ethanol cost to gasoline price. While costs would mostly be a function of technological progress and investment level, prices are much more dependent on the market. Thus gasoline prices will be dependent on the prices of competitive products as well as many other factors. To the extent it is not already factored in, the price of gasoline is likely to fall below estimated levels as a direct reaction to significant increases in ethanol production replacing demand for gasoline. Such pricing changes would push the date for competitive ethanol further out.

This analysis also ignores the effects of non-price barriers on the growth of ethanol demand, hence implicitly assuming that there will be sufficient demand for ethanol to meet mandated production levels. This would require the demand side changes discussed in Section 2 to occur in tandem with the production improvements.

Conclusion

The U.S. is at an important crossroads. The ability to significantly increase renewable fuel consumption requires both changes in the vehicle fleet and in fuel production capacity. For the next three years business as usual can proceed, with traditional corn-based ethanol production increasing from 10 billion gallons to 15 billion gallons. This can be consumed with little change to the vehicle fleet by incorporating universal E12 and slightly higher refueling rates for the current flex-fuel vehicles. However, in order to meet even the near-term goals set by the Energy Independence and Security Act of 2007, 20 billion gallons of alternative non-corn-based biofuel must start coming online now, along with the infrastructure needed to distribute the fuel nationally.

At the same time, considerable changes need to be made to the demand side in order to meet the RFS2 standards. First, assuming it is technically feasible, we recommend changes to the current U.S. Environmental Protection Agency limits on the amounts of ethanol that can be blended into regular gasoline. This is because for every percentage increase to the universal ethanol-gasoline blend, consumption of ethanol increases by close to 1.5 billion gallons. Second, we recommend significantly increasing the FFV fleet (along with the required refueling stations), because for every million additional FFVs in the fleet the capacity for ethanol increases by almost a billion gallons per year. Meeting the RFS2 standards requires a combination of these two approaches.

On the supply side, some significant changes need to occur by 2012, since we have neither the capacity nor the technology to produce more biofuels that will meet regulatory requirements. While the technology for corn-based ethanol is mature, there is a regulatory limit on additional corn-based production due to its greenhouse gas emission implications.[64] For 2010, the EPA chose to reduce the requirement from 100 millions gallons of cellulosic ethanol to 6.5 millions gallons because the required capacity was not online. If the EPA is to adhere to the future standards previously set by the EISA, we would need to see an increase in the investment for cellulosic technology and production plants.

Assuming technological innovation, the estimated magnitude of the investment needed to meet the supply mandates is not insurmountable, and totals about $66 billion. This cost estimate includes capital investment for cellulosic ethanol production of about $50 billion, $12 billion for new distribution infrastructure, and $4 billion for corn ethanol, offset slightly by $8 billion in avoided investment in petroleum refining.

The spotlight is now on policy-makers and investors as they try to take cues from each other in moving forward. Fulfilling the mandate will require significant investment; however, the chicken and egg problem looms, as investors remain wary of committing to a mandate that regulators will not enforce, and regulators will not enforce a mandate that cannot be met. To crack this cycle and strengthen the case for higher renewable fuel standards, policy-makers need to renew their commitment to the mandated goals, and make it explicitly clear that if the technology and capacity are there, they will enforce the mandates.

Endnotes

[1] Congress mandated 36 billion gallons of biofuel annually by 2022, including one billion gallons of biodiesel. For the purposes of this paper, we are ignoring biodiesel; thus, we are solely concerned with the 35 billion gallons of non-diesel biofuel.

[2] Throughout this paper "Exx" will be used to denote the percentage of ethanol in that particular blend of gasoline.

[3] According to the "Advanced Biofuels tracking database" compiled by the *Biofuels Digest* (updated release 1.1, March 2010), the U.S. had a nameplate capacity of 4.40 million gallons of advanced biofuels in 2009 and 1.37 billions gallons of capacity planned for production by 2014. Available at: http://biofuelsdigest.com/bdigest/2010/03/02/advanced-biofuels-capacity-will-increase-to-1-7-billon-gallons-by-2013-downloadable-database.

[4] See "EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond," EPA420-F-10-007, U.S. Environmental Protection Agency, February 3, 2010. Available at: http://www.epa.gov/oms/renewablefuels/420f10007.htm.

[5] Dunhum, Sarah, "Renewable Fuel Standard: Rulemaking Update," Biomass Research and Development Technical Advisory Committee Meeting, June 2-3, 2009. Available at: http://brdisolutions.com/Site%20Docs/Forms/DispForm.aspx?ID=392&RootFolder=%2fSite%20Docs%2fTAC%20Meeting%20June%202009&Source=http%3a%2f%2fbrdisolutions%2ecom%2fSite%20Docs%2fTAC%20Meeting%20June%202009.

[6] Ethanol is not suitable for use in jet fuel due to its lower energy content. Therefore, the only way to meet the mandate is through ground transportation fuel.

[7] "EPA Proposes New Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond," Regulatory Announcement EPA420-D-09-023, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, May 2009.

[8] "Task Force on Biofuels Infrastructure," National Commission on Energy Policy, p. 9. Available at: http://www.energycommission.org.

[9] "United States Ethanol Production for 2008 exceeds 9 billion gallons," Azo Cleantech. Available at: http://www.azocleantech.com/details.asp?NewsID=4833.

[10] Defined in Title II Section 201 of the EISA. There is a fourth individual mandate for one billion gallons of biodiesel.

[11] Each type of fuel must also meet certain emissions reduction standards, calculated over the full lifecycle of the fuel; that is to say they include emissions as a result of land-use changes and acquiring feedstock, in addition to the actual combustion in the car engines. Each of the GHG reduction goals can be lowered by up to 10 percent in a given year if the EPA determines the standard is too stringent. The EISA allows for all biofuel facilities that "commenced construction" prior to the enactment of the EISA to be grandfathered in and not held to the 20 percent GHG emission reduction for conventional biofuel. (See Title II Section 201 of the EISA.)

[12] "Current usage" is based on the Energy Information Administration (EIA), "Annual Energy Outlook 2010 Early Release Overview," December 14, 2009, (hereafter AEO 2010) estimate (Table 17, 2009 value). "Move to universal E10" is 10 percent of current motor gasoline usage (AEO 2010, Table 11, 2009 value) less the "current usage". "Move to E12" is the 12 percent of the current motor gasoline usage less the "move to universal E10" estimate. "Raise refuel rate" estimate is based on estimate of eight million FFVs and the U.S. Environmental Protection Agency's "Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program," EPA420-D-9-001, May 2009, (hereafter DRIA) estimates of average miles traveled (12,000) and fuel economy (18 mpg) and 1.3 gallons of E85 to one gallon of traditional gasoline. Consumption due to increase in FFVs is calculated similarly.

[13] DRIA, p. vii & 202.

[14] Based on the blended ethanol and motor gasoline consumption for 2009 in the AEO 2010, Tables 11 and 17.

[15] DRIA, p. 202.

[16] Calculated as 10 percent of the 2009 motor gasoline consumption (138 billion gallons). Estimates are from the AEO 2010 forecast.

[17] EPA Regulatory Announcement, p. 5.

[18] Assuming the amount of ethanol used in E85 does not substantially increase, the required mandate will be more than 10 percent of the expected 2010 motor gasoline consumption of 145 billion gallons.

[19] http://www.reuters.com/articleidUSN0933048220090309?sp=true.

[20] "Preliminary Test Report Shows No Significant Change in Vehicle Emissions from Intermediate Ethanol Blends," *Green Car Congress*, October 7, 2008. Available at: http://www.greencarcongress.com/2008/10/preliminary-tes.html.

[21] Intermediate Fuel Blends, p. xvi – xviii. Results show that fuel economy, vehicle emissions, catalyst temperatures, and operability indicated no problems with blends up to E20.

[22] Based on the AEO 2010 estimates of motor gasoline consumption (Table 11) and assuming E85 usage does not increase.

[23] "Flex-Fuel Vehicles." Available at: http://www.fueleconomy.gov/feg/flextech.shtml.

[24] U.S. Department of Energy. Available at: http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel.html.

[25] Hess, Glenn, "Renewable Fuels Face Bumpy Road," *Government & Policy*, September 17, 2007, p. 28- 30. Available at: http://pubs.acs.org/cen/government/85/8535gov1.html.

[26] Assuming FFV owners travel 12,000 miles per year and get 18 miles per gallon on average. Estimate also assumes that 1.3 gallons of E85 is required to travel the same distance as a gallon on gasoline. DRIA, p. 255.

[27] DRIA, p.225.

[28] "Bioenergy Conversion Factors," Oak Ridge National Laboratory, October 6, 2009. Available at: http://bioenergy.ornl.gov/papers/misc/energy_conv.html.

[29] Comparison includes all 2010 model vehicles with E85 compatible engines and overall mileage is a simple average of city and highway mileage. January 19, 2010. Available at: http://www.fueleconomy.gov.

[30] The difference is expected to be even higher because of the consumer inconvenience of more frequent refueling due to the lower energy content of ethanol.

[31] "National E85 Price Report," by E85prices.com. July 20, 2009. Available at: http://e85prices.com/index.php.

[32] DRIA, p. 229-230.

[33] "Task Force on Biofuels Infrastructure," p. 13. Worse, only one in four FFVs has sufficient access to E85 in the ZIP code in which it was purchased to use E85 (see DRIA, p. 256).

[34] "Task Force on Biofuels Infrastructure," Appendix B, p. 14.

[35] For more detailed information, see U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy website at: http://www.nrel.gov/docs/fy03osti/33058.pdf.

[36] U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy website. Available at: http://www.afdc.energy.gov/afdc/data/vehicles.html.

[37] AEO 2010, Table 58.

[38] Woodrow Wilson International Center for Scholars, "The Global Dynamics of Biofuels - Potential Supply and Demand for Ethanol and Biodiesel in the Coming Decade," Brazil Institute Special Report, April 2007, Issue No. 3, p. 5-6. Available at: http://www.wilsoncenter.org/topics/pubs/Brazil_SR_e3.pdf.

[39] http://en.wikipedia.org/wiki/Flexible-fuel_vehicle.

[40] DRIA, p. 63.

[41] According to the Advanced Biofuels tracking database compiled by the *Biofuels Digest* (updated release 1.1, March 2010), cellulosic ethanol nameplate capacity for year-end 2009 was 2.95 million gallons and is expected to increase to 33.45 gallons by year-end 2010. Available at: http://biofuelsdigest.com/bdigest/2010/03/02/advanced-biofuels-capacity-will-increase-to-1-7-billon-gallons-by-2013-downloadable-database.

[42] "Building Cellulose: U.S. Cellulosic Ethanol Plants New or Under Construction," by Grainnet.com. Available at: http://www.grainnet.com/pdf/cellulosemap.pdf. Also "Task Force on Biofuels Infrastructure," p. 41-43.

[43] "Biofuels Can Provide Viable, Sustainable Solution to Reducing Petroleum Dependence, Study Shows," *ScienceDaily*, February 11, 2009. Available at: http://www.sciencedaily.com/releases/2009/02/090210133920.htm.

[44] DRIA, p. 70-72. The EPA predictions have an average plant capacity of 40 million gallons per year from 2010 to 2013, 80 million gallons per year from 2014 to 2017, and 100 million gallons per year thereafter. Together with increasing build rates from 2 plants in 2010 to 20 plants in 2022 would put the U.S. at about 16 billion gallons per year in 2022.

[45] DRIA, p. 72.

[46] These are only investment costs, and do not include incremental investments necessary to run or maintain the facilities.

[47] DRIA, p. 621. Note that these figures include only distribution costs in the U.S. and only the estimated costs due to RFS2, i.e., over the EIA's "Annual Energy Outlook 2007," February 2007, (hereafter AEO 2007) reference case, and attributed to ethanol (DRIA, p. 572-573). The negative figure for petroleum refining indicates the predicted lack of investment in tradition gasoline due to the lower required volume under RFS2.

[48] DRIA, p. 547.

[49] "Task Force on Biofuels Infrastructure," p. 13. However, in the future, E85 might be produced in a more geographically diffused fashion and hence might reduce the need for transportation paths to the blending centers.

[50] "Safe & Reliable Ethanol Transportation & Storage Technology Roadmapping Workshop," CC Technologies and Energetics Incorporated, October 25-26, 2007, Dublin Ohio, Summary Results, November 2007. Available at: http://aopl.orgposted/888/Ethanol_Transportation_Roadmap_Workshop_Results.192619.pdf.

[51] "Ethanol and Pipeline Transportation Policy Paper," Association of Oil Pipe Lines, February 2007, p. 1.

[52] "Task Force on Biofuels Infrastructure," p. 29.

[53] DRIA, p. 205.

[54] DRIA, p. 574. Note that these figures include only distribution costs in the U.S. and only the estimated costs due to RFS2 (i.e., over the AEO 2007 reference case). While difficult to precisely quantify, the AEO 2007 reference case predicts 13.2 billion gallons of ethanol will be used, compared to 34.1 billion gallons in this case. Thus these are the estimated infrastructure costs to accommodate the additional 20.9 billion gallons of ethanol by 2022.

[55] The total cost of constructing that many stations is estimated to be a minimum of $4 billion. Based on minimum of $150,000 per station from "Task Force on Biofuels Infrastructure," p. 53. The number in the table is $3 billion due to a projected growth of E85 stations in the base case, predominantly in the Midwest, absent RFS2.

[56] "Participação de carros flex nas vendas volta a bater 94%" (in Portuguese), UNICA, August 9, 2009. Available at: http://www.unica.com.br/noticias/show.asp?nwsCode=83CC5EC9-8E69-4C11-9F0E-CBDF9B849AE2.

[57] U.S. Department of Energy, "Alternative Fuel Fact Sheet," June 2008. Available at: http://www.afdc.energy.gov/afdc/pdfs/42953.pdf. Also from the website of the Union of Concerned Scientists, "Benefits and Limitations of Flex Fuel Vehicles," October 7, 2009. Available at: http://www.ucsusa.org/clean_vehicles/solutions/cleaner_cars_pickups_and_suvs/benefits-and-limitations-of.html.

[58] Barrionuevo, Alexei and Micheline Maynard. "Dual-Fuel Vehicles Open Mileage Loophole for Carmakers," *The New York Times*, August 31, 2006.

[59] The cost differential equals one minus one divided by the amount of pure ethanol required to equal the energy of one gallon of gasoline: $(1 - 1 / 1.519) \cong 35$ percent.

[60] Hettinga W. G., H.M. Junginger, et al., "Understanding the reductions in U.S. corn ethanol production costs: An experience curve approach," *Energy Policy*, 2009, p. 190–203.

[61] http://www.poet.com/news/showRelease.asp?id=181.

[62] National Commission on Energy Policy, "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges," December 2004.

[63] http://www.e85prices.com, December 2009.

[64] "EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond." Available at: http://www.epa.gov/oms/renewablefuels/420f10007.htm.

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