BIOFUELS INFRASTRUCTURE IN THE UNITED STATES: CURRENT STATUS AND FUTURE CHALLENGES

by

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A cross country assessment of early stages of implementation"

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Abstract

Ethanol production in the United States takes place in close proximity to the feedstocks used in its production. This means that most of the ethanol refineries are located in corn producing areas. Ethanol is blended at 10 percent by volume with virtually all gasoline sold in the United States and most ethanol must be transported great distances from corn producing regions to more populated regions in which the bulk of gasoline is used. Because Ethanol cannot feasibly be shipped by the existing liquid fuels pipeline network, almost all ethanol used in the United States is shipped by rail. Ethanol is blended with gasoline at major gasoline supply terminals before being trucked to fueling stations. A small fraction of fueling stations are equipped to sell gasoline with blends of ethanol greater than 10 percent. Those fueling stations with this capability are disproportionately located in ethanol producing regions. Biodiesel production also takes place near feedstocks and the product is typically shipped by rail to where the product is blended with conventional diesel and distributed. The challenges associated with building the infrastructure required to produce, deliver, and use larger volumes of biofuels fall into 3 categories; regulatory, technological, and market-based:

- A changing, varied and uncertain regulatory environment adds risk and may delay investments in biofuels infrastructure by producers, shippers, distributors and users of biofuels.
- Biofuel technologies as well as other alternative power train technologies will determine the volume of biofuels and of what type that can be integrated into transportation fuels.
- Production, transport, distribution, and automobile infrastructure must be coordinated for effective integration of increasing volumes of biofuels into the transportation fuels market. However, this coordination will require large infrastructure investments and the willingness of investors to finance this will depend to a large extent on the perceived willingness of consumers to adopt changing technologies and fuels.

Background

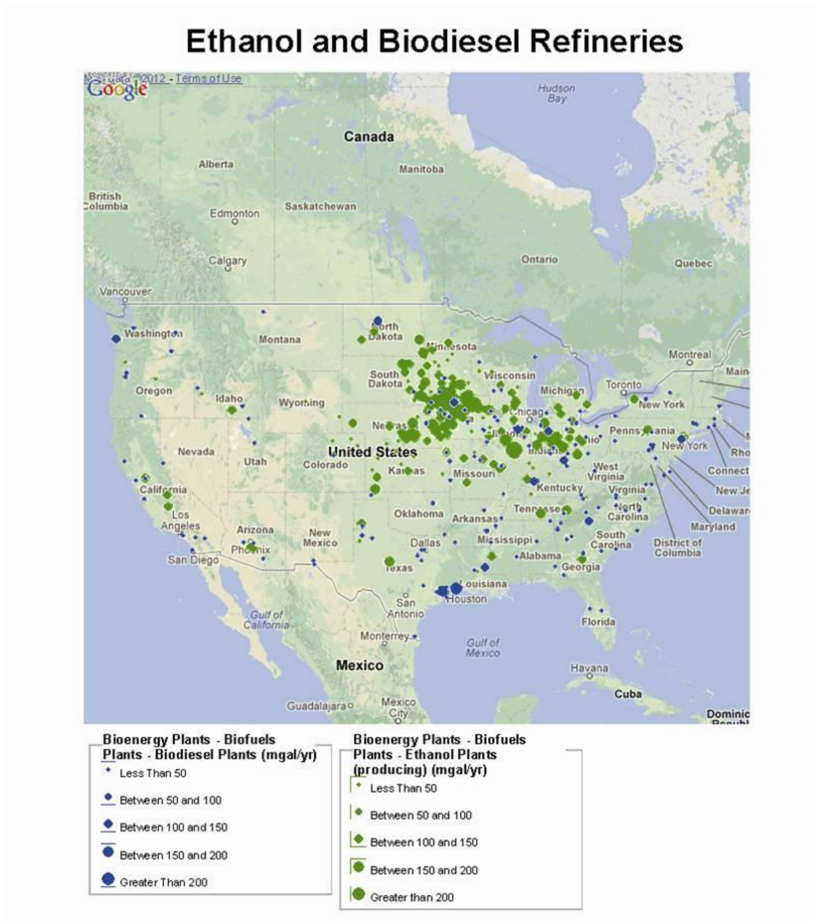
Biofuel use in the United States has grown rapidly over the past 3 years, reflecting both regulatory requirements and economic factors. Specifically, ethanol consumption accounted for approximately 8 percent of gasoline by volume in 2009 and in 2011 had risen to almost 10 percent. In 2012, the volume of ethanol blended into gasoline is on track to hit 10 percent. Biodiesel is a much smaller percentage of diesel sales, amounting to approximately 1.5 percent in 2011. By far, the majority of ethanol used as a liquid fuel, about 99 percent, is blended with gasoline at a level of 10 percent—so called E10—and almost every gallon of gasoline sold in the United States has 10 percent ethanol blended into it. Higher blends of ethanol exist—so called E85, which comprise blends of gasoline containing between 85 percent ethanol—but sales of these blends accounted for less than 1 percent of ethanol consumption in the United States in 2011. In addition, in January 2011, EPA approved the use of blends of 15 percent ethanol, E15, for use in light duty cars and trucks produced on or after 2011. To date, E15 has not been widely sold.

A number of laws and regulations at the federal, state, and local levels are important drivers of the growth of biofuels production and use in the United States. Currently, most of the ethanol used in the United States is derived from corn, while biodiesel typically derives from soybeans, other grains, and animal fats. The Renewable Fuels Standard (RFS2) requires annual increases in biofuels use in the United States, culminating in an almost tripling of biofuels use from the current level of about 13.6 billion gallons to 36 billion gallons by the year 2022. RFS2 calls for about 90 percent of this increase to come from advanced biofuels, including advanced cellulosic biofuels, advanced biomass-based diesel, and other unspecified advanced biofuels. Under the RFS2 requirements, corn-based ethanol is nearing the maximum allowable levels for domestic use, which will peak at 15 billion gallons per year in 2015. Most advanced biofuel production has not yet become viable at commercial scale. Sugar-based ethanol, primarily produced in Brazil qualifies as an advanced biofuel and this has led, in recent years, to cross trading of ethanol between the United States and Brazil, with corn-based ethanol being exported from the United States to Brazil as production has surpassed allowable domestic consumption, and sugar-based ethanol being imported to the United States from Brazil to meet requirements for advanced biofuel consumption.

Federal tax incentives have encouraged the production and use of biofuels as well as discouraged the importation of foreign supplies of ethanol. Specifically, the Volumetric Ethanol Excise Tax Credit (VEETC)—a tax credit of $0.45 per gallon of ethanol blended—which was allowed to expire at the end of 2011 had, for years, encouraged production and use of ethanol by reducing the cost to the blenders. In addition, an import tariff of $0.54 per gallon on foreign ethanol has discouraged the importation of ethanol, thereby further encouraging domestic production. A $1.01 per gallon tax credit for producers of biodiesel also encouraged its production.

Some states and localities have also implemented minimum biofuel requirements, both in terms of minimum volumes used as well as minimum production levels within those states. For example, the state of Oregon has an in-state production requirement for biodiesel as well as a graduated biodiesel content requirement for diesel sold in the state. The content requirement started at 2 percent in 2009 and is slated to grow by increments to 20 percent as in-state production of biodiesel increases. The city of Portland, Oregon has similar but more stringent biodiesel content requirements. New York City and the state of Vermont also implemented biodiesel content requirements for heating oil in 2012.

Figure 1



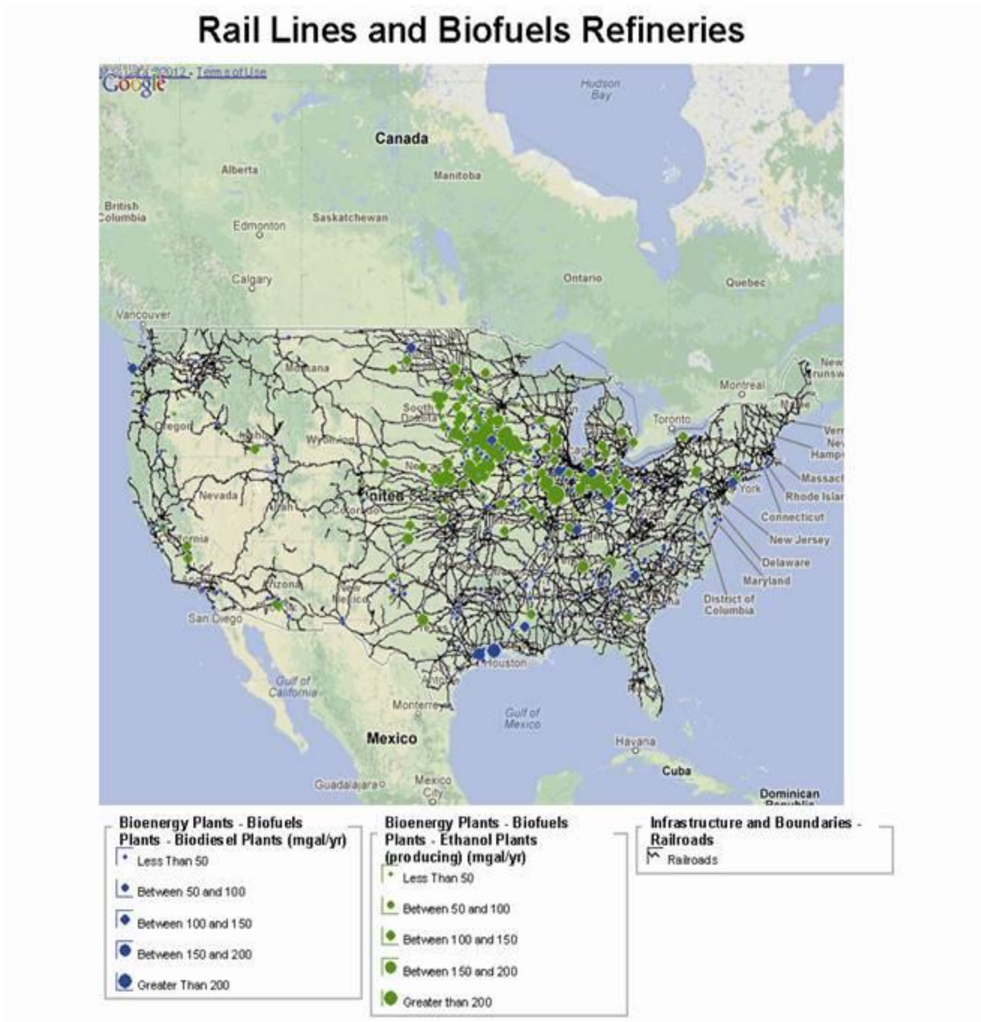
(Source: NREL BioFuels Atlas- http://maps.nrel.gov/biomass)

Biofuel Production, Transportation, and Distribution in the United States

Ethanol production in the United States takes place in close proximity to the feedstocks used in its production. The primary reason for this is that the weight of ethanol feedstocks is great relative to the weight of finished ethanol so transportation costs dictate that refineries be built in close proximity to stable sources of biofeedstocks. In the case of ethanol, most of the domestically produced ethanol is corn-based so most refineries have been built in the upper Midwest in the corn growing regions of the country.

Biodiesel refineries are, for similar reasons, located in close proximity to feedstock supplies, although the feedstocks used to produce biodiesel vary a great deal more than for ethanol. Biodiesel feedstocks include soybean oil, other vegetable oils, and animal fats, the latter typically byproducts from food production or preparation. The variability of biodiesel feedstocks has led to a wider geographic distribution of biodiesel refineries. Figure 1 shows the locations of ethanol and biodiesel refineries currently producing in the United States.

Figure 2



(Source: NREL BioFuels Atlas- http://maps.nrel.gov/biomass)

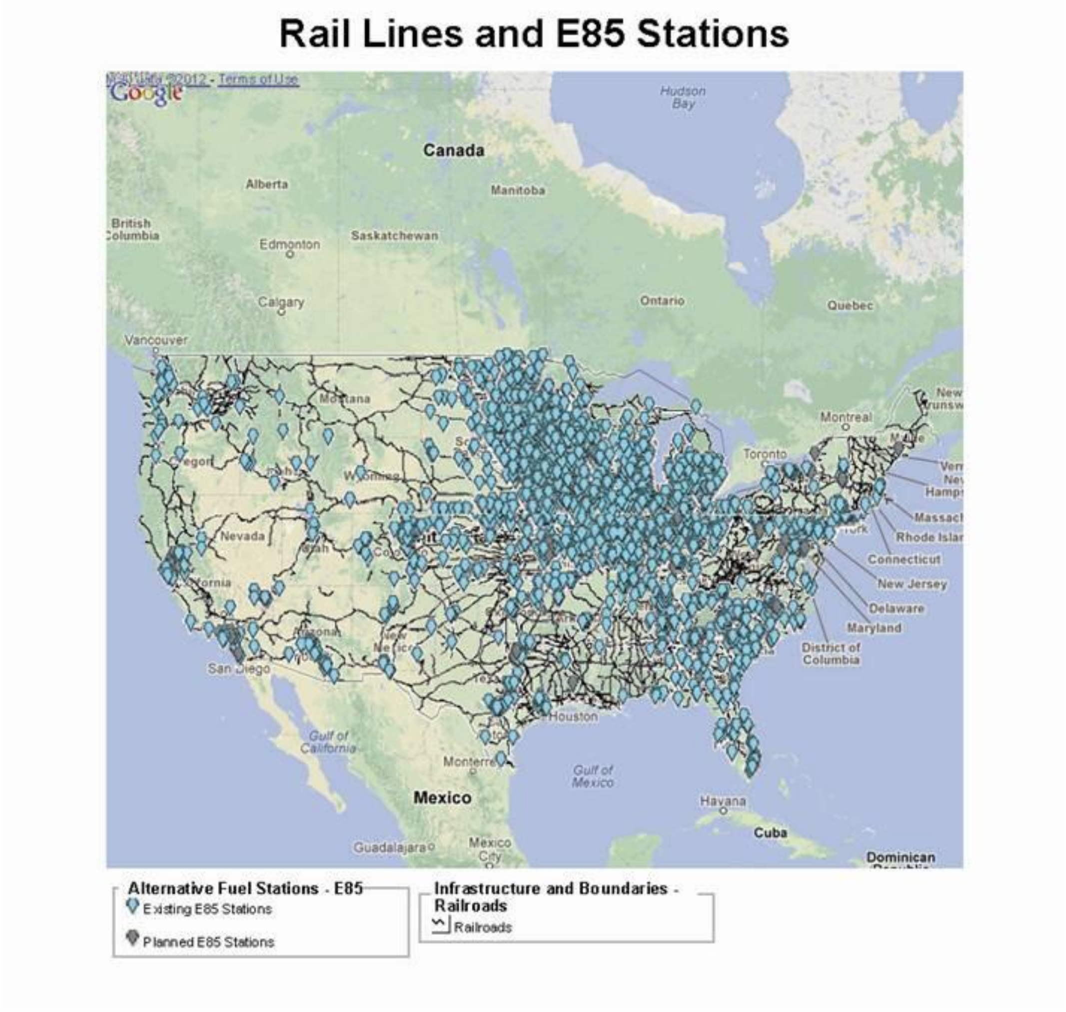
Transportation of biofuels to large liquid fuel terminals for blending and distribution to fueling stations currently relies primarily on rail. Ethanol cannot generally be transported in existing multi-fuel pipelines because ethanol is a strong solvent, which can potentially cause corrosion of pipelines and degradation of seals and other pump components. In addition, ethanol dissolves residues left in the pipelines from other fuels and absorbs water. As a result, ethanol traveling in pipelines could arrive at a terminal outside the range of allowable specification. This is particularly an issue at terminals where the ethanol will be blended with specially formulated gasoline created to meet strict air emissions requirements. As a result of the reliance on rail transport, biofuel refineries are built along existing rail lines. Increasingly, so called "unit trains," which are entire trains of tanker cars dedicated to a single cargo—in this case, ethanol or biodiesel—are being used. This is a more cost effective method for transporting large volumes of biofuels from refineries to major population centers. Figure 2 shows the rail network of the United States along with the locations of ethanol and biodiesel refineries.

As mentioned above, virtually every gallon of gasoline sold in the United States is blended with 10 percent ethanol, which is an upper bound on the amount of ethanol approved by automobile manufacturers for use in all but flex-fuel vehicles. Because of the concentration of ethanol refineries in corn growing regions—typically far from large populations—the distances that ethanol are transported are large and shipping is a significant fraction of the delivered cost of ethanol. The fact that almost all gasoline is already blended with 10 percent ethanol means that further increases in the use of ethanol will require higher blends of ethanol, either E85 or the recently approved E15. However, of the more than 120,000 fueling stations in the United States, only about 2,500 sell E85, and these stations are not spaced evenly around the country, making use of this fuel for long-distance travel inconvenient at best. E15 has yet to achieve widespread use, with only a few hundred fueling stations even having pumps capable of delivering variable ethanol blends. Figure 3 shows the locations of E85 stations—note that these stations are almost all located in close proximity to rail lines. Most biodiesel stations also tend to be located at or near biodiesel refineries as shown in figure 4.

Infrastructure Challenges Facing Expanded Production and Use of Biofuels in the United States

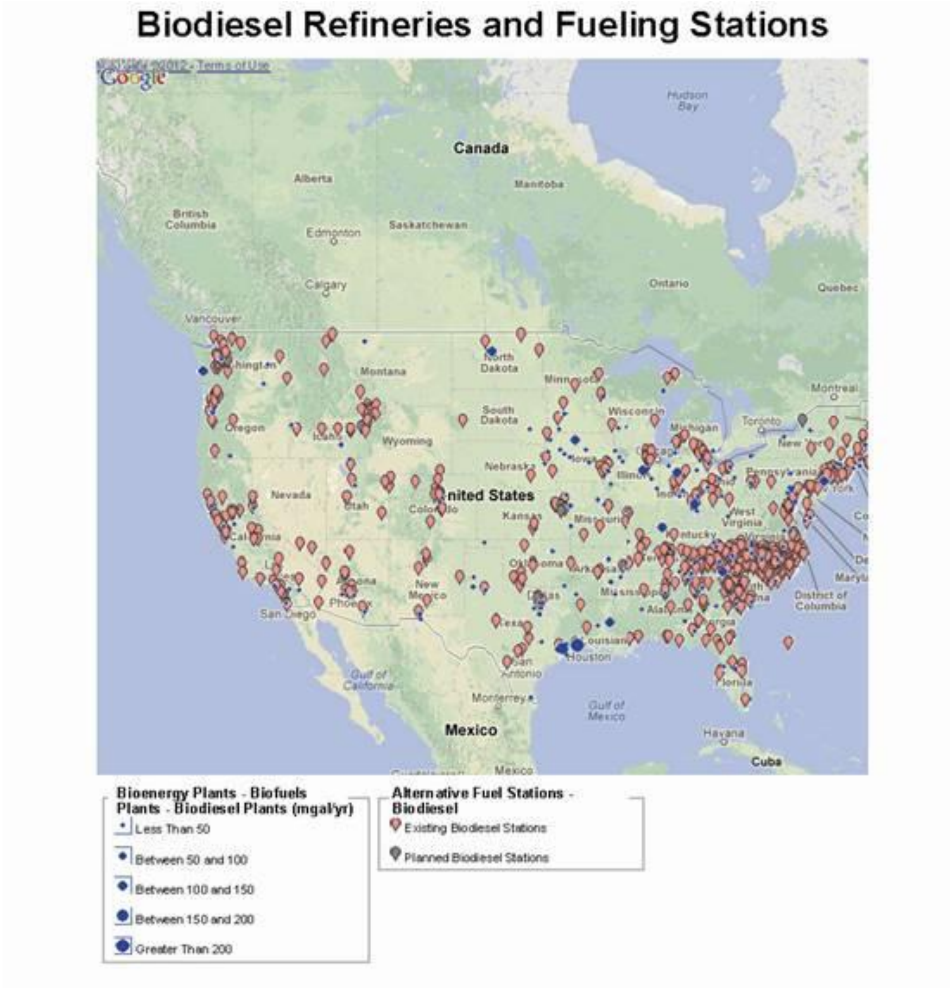
The challenges associated with meeting the RFS2 requirements for biofuel consumption fall into 3 categories; regulatory, technological, and market-based. A changing regulatory environment may increase the risk of making long-lived infrastructure investments by automobile manufacturers, fueling stations, rail lines, and consumers. Technologies for producing advanced biofuels have been slow to develop and infrastructure investment associated with transportation or use of these fuels must wait until commercially viable production processes emerge or alternative power train solutions change the picture more dramatically. Investments in infrastructure require coordination among a wide array of stakeholders, including auto manufacturers, biofuels manufacturers, wholesale liquid fuel dealers, fueling station owners, and consumers; failure to achieve consensus may slow the development of infrastructure needed to meet RFS2 requirements in the near to mid-term.

Figure 3



(Source: NREL BioFuels Atlas- http://maps.nrel.gov/biomass)

Figure 4



(Source: NREL BioFuels Atlas- http://maps.nrel.gov/biomass)

Changing, Variable, and Uncertain Regulatory Environment Poses Challenges to Assessing Infrastructure Investment Risk

The regulatory environment surrounding biofuels and transportation fuels more generally has been in a state of flux and varies across jurisdictions, creating uncertainty about future infrastructure requirements for biofuels production and use requirements. In addition, uncertainty about broader energy, climate, and environmental goals, policies, and regulations may add to the complexity and risk associated with making long-lived biofuels infrastructure investments. For example:

- Direct subsidization of biofuels, through federal tax credits has, in the case of the VEETC, expired, and in the case of biodiesel credits is currently up for review in a tight budget environment. To the extent that such subsidies are required to encourage development of advanced biofuels, the expiration or reduction in governmental support could change the path of development of these fuels.

- Biofuel production and use requirements vary across federal, state, and local jurisdictions and may lead to a further Balkanization of the liquid fuels markets. As previously mentioned above, a number of states and even cities have differing requirements for biodiesel use and state production requirements. Because liquid fuels markets are national and even international in some instances, requiring multiple different blends of biofuels in conventional liquid fuels could reduce the fungibility of liquid fuels and lead to friction in these markets.

- EPA recently harmonized greenhouse gas rules for automobiles with the requirements under CAFE standards to increase the fuel efficiency of the light duty motor vehicle fleet. To the extent that future, more stringent greenhouse gas emissions limits or more stringent CAFE standards require further improvements in fuel efficiency, this could lead to falling demand for liquid fuels. In turn, this would make adding more biofuels to the liquid fuels mix more challenging. In addition, subsidies and other federal, state, and local efforts to encourage the use of electric vehicles has the same potential effect.

- Different biofuel feedstocks and production processes have different implications in terms of life-cycle water use, criteria air pollutants, land use effects, and greenhouse gas emissions. As such, biofuel production and use is potentially subject to changes in any policies directed at these broader issues.
    - For example, California's recently promulgated rule on low carbon fuel standards will, if it survives legal challenges, lead to changes in domestic ethanol production practice and potentially encourage additional imports of sugar-based ethanol. Specifically, domestic producers can reduce life cycle greenhouse gas emissions by switching from coal to natural gas as a fuel to power their refineries and by selling wet rather than dry distillers grains—a valuable byproduct of corn-based ethanol production.

    - Sugar-based ethanol intrinsically has a smaller carbon footprint than corn-based ethanol because the latter requires an additional refining step to isolate the sugars in the corn. As a result, policies requiring lower life cycle greenhouse gas emissions could dictate a shift from corn- toward sugar cane-based ethanol production and therefore toward swapping domestically produced ethanol for ethanol from foreign producers thus adding further transportation costs.

    - Expanding biofuels production dramatically over the next decade as the RFS2 calls for will put further pressure on agricultural lands, water supplies, and have implications for sustainability more broadly, potentially putting biofuels on a collision course with other broader social goals. For example a recent NRC study on algal-based biofuels—a promising potential source of advanced biofuels—identified a number of sustainability concerns, including availability of water, suitable land, and life-cycle greenhouse gas emissions, among others.

<u>Technological Challenges and Biofuels Infrastructure</u>

The future mix of biofuels available in the market will depend on the nature and speed of technological advancement and will require expansion and potentially changes to the modes of liquid fuels transportation and distribution, and the motor vehicle fleet. However, until the path of technological innovation through to commercialization is clear, making infrastructure investments will be fraught with risk.

There are many potential paths for advanced biofuels, each with specific challenges requiring different infrastructure solutions. For example:

- Algal-based biofuels may be created using a wide range of processes but, in general, involve growing algae in a condensed form in water, introducing high concentrations of carbon dioxide and harvesting lipids for further processing into liquid fuels. In addition to advances in the technology of creating consistent lipids from algae, doing this at a commercial scale will involve delivering reliable sources of carbon dioxide, finding or delivering water supplies that are appropriate for this use, and transporting the valuable and waste products of the process to where they can be used or disposed of. The precise nature and cost of infrastructure required to commercialize algae-based biofuels cannot be known until successful and scalable demonstration occurs. Some algal-based biofuels may be able to drop into the feedstock stream of traditional petroleum refineries, in which case they may also be able to be shipped in existing pipelines to the extent those pipelines coincide with the location of the biofuel production facilities.

- Biomass-based diesel can be made from a number of vegetable oils or animal fats and the scale of production is primarily limited by competition for land to grow feedstocks, land that has alternative uses including growing food crops. If biomass-based diesel is to expand much, the infrastructure needed to support this will primarily be associated with new production facilities and additional rail capacity. Beyond that, there is the issue that not all biodiesel is mutually compatible, and to the extent that biodiesel use expands, additional storage and blending infrastructure may be required to avoid blending incompatible fuels.

- Cellulosic ethanol is potentially an attractive biofuel from the standpoint of land use, water consumption, and lifecycle greenhouse gas emissions. Cellulosic processes can produce ethanol from biomass grown on marginal lands and that does not require large amounts of fresh water. This would also not put additional pressure on food prices. However, marginal lands with enough available water and that are near existing rail lines are limited and the costs of building additional transportation infrastructure would be quite large. Further, as will be discussed below, adding more ethanol to the mix will require a broad consensus of decision makers.

- Finally, other power train alternatives to fossil liquid fuels, such as electric vehicles or hydrogen fuel cell technologies could overtake advanced biofuel technologies, obviating the need for additional biofuel infrastructure and, perhaps, making some existing infrastructure obsolete.

Creating Consensus in an Uncertain Environment

Expansion of biofuels production and use will require large infrastructure investments in production, transport, distribution, and automobile manufacture. All these investments will have to be coordinated for effective integration of increasing volumes of biofuels into the transportation fuels market. Further, the willingness of investors to finance this will depend to a large extent on the perceived willingness of consumers to adopt changing technologies and fuels. Illustrations of the complexity of the coordination required include:

- Using higher blends of ethanol will require significant changes to the vehicle fleet. Specifically, E15 has not taken hold in the market, in part, because automobile manufacturers have not approved its use and may void the warranty of automobiles using it. In general, burning higher blends of ethanol than E10 requires changes to the combustion cycle, depending on the specific blend used and also may require replacement or alterations to certain fuel line or engine components. Such flex-fuel vehicles exist and can be produced at a small cost penalty compared to standard vehicles. However, there is a slight performance and fuel economy penalty associated with flex fuel vehicles and it is a risk for automobile companies to make such vehicles on the speculation that the fuel supply will change in a particular way. Because it takes at least 7 years for the vehicle fleet to turnover half way, this part of the infrastructure may be the slowest to adapt if advanced biofuels requirements lead in the direction of additional ethanol. Intermediate grades of ethanol will also require investments in new pumps and/or tanks at fueling stations at a cost estimated to be between $22,000 and $100,000 per station. It is unlikely that many station owners will choose to incur such costs without some assurance that intermediate blends will become widely used and that the prices they can charge for them will generate a positive return on the investment.

- For consumers to fully embrace biofuels—particularly higher blends of ethanol—it will become imperative that the prices of different blends of biofuels reflect in a competitive way, the energy density contained per gallon of these fuels. Because ethanol is less energy dense than gasoline, each incremental addition of ethanol to the gasoline blend will necessitate a reduction in the price per gallon so that the cost per mile travelled is equalized. To date, prices of E85 and E10 have not typically reflected this difference in energy density. For example, EIA recently reported that

U.S. average E85 prices in January and July of 2012 were approximately 90 percent the price of E10. However, because E85 has only about 76 percent of the energy content of E10, E85 cost more per mile driven than E10 in these months.

- Shippers of biofuels will also have to expand rail capacity or build dedicated pipelines to facilitate the expansion of biofuel use. As with automakers, fueling station owners, and consumers, shippers will be reluctant to expand capacity unless and until greater certainty about the future of biofuel production and use is more certain.

Conclusions

In recent years the targets for advanced biofuels laid out in EPA's RFS2 have not been met, requiring EPA to reduce the requirements. Technology is advancing but commercial production of advanced biofuels does not appear to be on the near horizon. Other alternatives to fossil liquid fuels are also technically feasible and remain potential competitors to increased biofuels production and use. Increased domestic production of biofuels also faces challenges associated with competing uses for land and water as well as other environmental and climate considerations. These factors lead to a high degree of regulatory and technological uncertainty about the future of biofuels, which will make it very difficult to build consensus among all the segments of the liquid fuel value chain about the shape and pace of infrastructure investment.

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§ This draft draws liberally from the sources listed above. Any errors are the responsibility of the author.