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A literature review of the market effects of federal biofuel policy and recommendations for future policy

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A literature review of the market effects of federal biofuel policy and recommendations for future policy

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ABSTRACT

The United States has had a federal biofuels policy since the 1970s. The purpose of this policy was to help the development of a biofuel industry during a time of high fuel prices in order to provide a domestic alternative to expensive foreign oil. Later the policy was changed to help lower the environmental impact caused by conventional fuels. Since that time the industry has grown and currently produces around 15 billion gallons of biofuels every year.

The current federal biofuel policy is largely based on one program, the Renewable Fuel Standard (RFS), which mandates the production and blending of several different classes of biofuels and provides a form of subsidy to the biofuel industry. This paper examines the market effects of the federal biofuel policy and provides recommendations for improving the policy to counteract any negative effects.

Federal biofuel policy has many far-reaching market effects. Some are easily calculable through expenditures and lost revenues, while others are harder to quantify because their full effects are not yet known. By evaluating these market effects, this paper will provide ample evidence that the federal biofuels policy needs to change, and will show what effects these changes could induce.

The biofuels industry largely owes its existence to government policies, however as the research shows the industry can now stand on its own. This paper will examine what will happen if the federal policy is eliminated and what the future of the biofuels industry could hold. Based on these examinations, it is unlikely that the industry needs further government support and policies should be adjusted in light of this.

CHAPTER 1: OVERVIEW

The United States, like other developed nations, relies on the transportation of goods and people to support its economy. The transportation infrastructure of the United States relies on vehicles powered by non-renewable fossil fuels. Currently, the United States uses 27% of annual world oil production (EIA, 2010b). Due to the United States's insatiable thirst for oil, two major concerns have developed at the national level: energy security and environmental protection. The United States imports between half and two-thirds of the oil it consumes (EIA, 2009a, Tyner 2007). This demand for oil also causes nearly a third of all carbon dioxide emissions in the US (EPA, 2010a). In order to address these concerns Congress has passed several pieces of energy legislation, one of the most recent being the Energy Independence and Security Act of 2007 (110. PL 140), which was passed:

> To move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes.

Under this law, Congress continued its long support of biofuels, including corn-based ethanol, soy biodiesel, and cellulosic ethanol (still commercially unviable) through an update to the Renewable Fuels Standard.

In recent years three main policies have been used to encourage biofuels production: the Volumetric Ethanol Excise Tax Credit (VEETC), often called the blender's credit; an Import Duty on Fuel Ethanol, often referred to as the ethanol import tariff; and the Renewable Fuel Standard.

The blender's tax credit is given to companies who mix ethanol and gasoline to make gasohol. The tax credit has been set at different levels, but was most recently at 45 cents per gallon until it expired at the end of 2011. The blender's tax credit has been the most controversial biofuels policy, because it is seen as a subsidy to produce ethanol from corn.

The ethanol import tariff was created by Congress to protect domestic producers of ethanol from cheap sugar-based ethanol imported from South America. The import tariff charged 54 cents per gallon of imported ethanol plus 2.5% of market price of the ethanol. Like the blender's tax credit, the ethanol import tariff expired at the end of 2011.

The Renewable Fuel Standard remains the main federal biofuels policy and was enacted in its current form in the Energy Independence and Security Act of 2007. The Renewable Fuel Standard requires the blending of biofuels in four categories: conventional biofuel, advanced biofuel, cellulosic biofuel, and biomass-based diesel. What each category requires will be discussed later. The Renewable Fuel Standard will eventually require 22 billion gallons of biofuels be blended in 2022. Companies that do not meet the blending requirements are fined up to $37,500 per day. However the EPA can waive the penalty if the means to produce the biofuel do not exist (EPA, 2011).

History of Biofuels Policy

Federal biofuels policy began as a way to support domestic energy production during the energy crisis of the late 1970s. The first policy development came from the Energy Tax Act of 1978, which gave blenders of ethanol an exemption from the federal gasoline excise tax of 4 cents per gallon of blended gasohol for a blend of up to 10% ethanol (CEC, 2004). Table 1 shows a complete list of legislative changes to federal biofuels policy. Chief among them was the creation of an income tax credit in addition to the excise tax exemption. (The law required that any excise tax credit taken be deducted from the income tax credit claimed, ensuring no overlap of tax credits.) When Congress passed amendments to the Clean Air Act that required gasoline to contain a higher percentage of oxygen to reduce air pollution, two main oxygenates were used: ethanol and methyl tertiary butyl ether (MTBE), until MTBE was gradually phased out at the state level due to environmental safety concerns. This demand for oxygenate was the largest driver of ethanol expansion during the 1990s (EIA 2009b). The largest change in biofuel policy since the creation of the tax credits was the Renewable Fuels Standard. At the end of 2011, the VEETC for corn based ethanol and tax credit for soy biodiesel were allowed to expire along with the import tariff. The subsidy for the blending of cellulosic ethanol is set to expire at the end of 2012. While the VEETC was allowed to expire, legislative history shows that the biodiesel tax credit has expired and been renewed retroactively. Because of this, they will continue to be discussed, even though renewal is unlikely for funding reasons. The VEETC and import tariff are unnecessary and should be avoided for reasons discussed later in this paper.

Future Transportation Fuel Needs

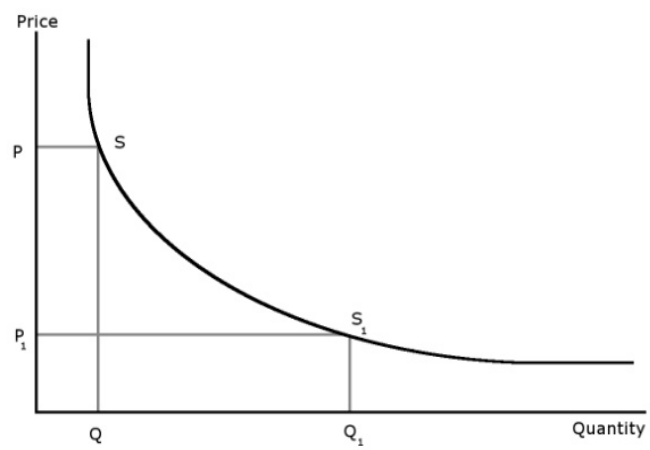
It is projected that the United States will demand 15 million barrels of crude oil based transportation fuel per day by 2022 and 16 million barrels per day by 2035 (EIA, 2010a). While total demand will increase, the rate of increase is expected to slow due to greater fuel efficiency and higher use of biofuels to replace some fossil fuels. However, fuel efficiency isn’t a solution. The Jevons paradox is an economic theory that states when efficiency rises, consumption doesn’t drop, because a lower price causes increased demand. If the Jevons paradox holds true in this case, the increased efficiency will increase fuel use, not decrease its use. Fuel follows a negative exponential demand curve, meaning there is a group of

Table 1: History of Legislative Policy Changes

1978	Energy Tax Act	Created a federal gasoline excise tax exemption for blenders of ethanol of 4 cents per gallon for a blend of up to 10% ethanol
1980	Energy Security Act	Created a loan guarantee program for the construction of ethanol plants
1980	Crude Oil Windfall Profit Tax Act	Ethanol excise tax exemption was extended until 1992 and an income tax credit of 40 cents per gallon was created
1980	Omnibus Reconciliation Act	Ethanol import tariff was created
1980	Gasohol Competition Act	Prevented gasoline marketers from discouraging the use of gasoline blended with ethanol
1982	Surface Transportation Assistance Act	The excise tax exemption was raised to 5 cents per gallon of gasohol and gas excise tax was raised to 9 cents
1984	Tax Reform Act	Excise tax exemption raised to 6 cents per gallon of blended gasohol, income tax credit raised to 60 cents per gallon of ethanol
1990	Omnibus Budget Reconciliation Act	Reduced excise tax exemption to 5.4 cents per gallon of gasohol, reduced income tax credit to 54 cents per gallon of ethanol, extended both tax credits until 2000, introduced small ethanol producers income tax credit of 10 cents per gallon of ethanol
1990	Clean Air Act Amendments	Required gasoline in 31 urban areas to contain higher percentage of oxygen to reduce air pollution, ethanol fulfilled this requirement
1998	Transportation Efficiency Act of the 21st Century	Lowered excise tax exemption to 5.1 cents per gallon of gasohol, lowered income tax credit to 51 cents per gallon of ethanol and extended both through 2007
2004	American Jobs Creation Act	Replaced the excise tax exemption with a tax credit and renamed the program the Volumetric Ethanol Excise Tax Credit (VEETC)
2005	Energy Policy Act	Created the Renewable Fuels Standard (RFS) mandating the production of 7.5 billion gallons of ethanol to be blended by 2012
2007	Energy Independence and Security Act	Increase the RFS mandate to 36 billion gallons by 2022 including conventional biofuels, advanced biofuels, cellulosic biofuels, and biomass based diesel.
2008	Food, Conservation, and Energy Act (Farm Bill)	Reduced the tax credit to 45 cents per gallon of ethanol once blending reached 7.5 billion gallons per year
2011	The VEETC was allowed to expire along with the ethanol import tariff leaving the RFS as the only major biofuel policy still in place	
CEC, 2004, Energy Policy Act, 2005, 110 PL 140, 110 PL 234		

consumers who will demand a certain quantity of fuel at any price. But as the price decreases, the number of consumers who demand fuel increases, as more people can afford to take driving vacations to, say, the Grand Canyon. This decrease in price could cause an increase in demand that eliminates any fuel savings from increased efficiency. As Figure 1 illustrates, a decrease in market price increases demand, requiring greater supply. Jevons paradox has long been debated and its accuracy is unknown, however future changes in the

Figure 1: Fuel Demand Curve



transportation fuel market may help decide on its accuracy. With domestic production of oil peaking in 1970 at 9.6 million barrels per day, the future increase in oil production will continue to rely on foreign oil sources (EIA, 2009b). With the passage of the Energy Independence and Security Act and update to the Renewable Fuel Standard, the government mandated an increase in production of renewable fuels. As part of this mandate Congress defined “renewable fuel” as “fuel that is produced from renewable biomass and that is used to reduce the quantity of fossil fuel present in a transportation fuel” (110 PL 140). The Renewable Fuel Standard, in addition to defining renewable fuels, created four categories, each with requirements on greenhouse gas (GHG) emissions and blending mandates. To measure GHG emissions, a life-cycle analysis (LCA) must be completed. An LCA measures the GHG emissions throughout the entire production process: from any land use change, the production, growth, and harvest of the bioenergy feedstocks such as corn and soybeans, the production of the biofuel, and any transportation of the fuel.

The first category of the RFS is conventional biofuel, including corn-based ethanol, which must have life-cycle GHG emissions of 20% below traditional gasoline. The RFS mandates 15 billion gallons of conventional biofuels be produced per year by 2015. The second category is advanced biofuels, including ethanol made from raw materials other than corn, such as sugar, that reduce life-cycle GHG emissions by 30% compared to gasoline. Advanced biofuels make up 4 billion gallons of the RFS. The third category is cellulosic ethanol made from cellulose, hemicellulose, or lignin from a renewable biomass, which has a life-cycle GHG emissions reduction of 60%. The RFS mandates 16 billion gallons be produced annually by 2022. The final category is biomass-based diesel, including soy biodiesel, that has a life-cycle GHG emissions reduction of 50%. This category requires 1 billion gallons be produced to meet the RFS mandate.

Biofuels Production

In order to better understand biofuels policy, it is important to have an understanding of how biofuels are produced. There are two general sources for bioenergy: food-based and nonfood-based feedstocks. Food-based feedstocks include corn, soybeans, sugar, and vegetable oils; nonfood-based feedstocks include crop-residues, dedicated bioenergy crops, and municipal solid waste. While there are diverse feedstocks and production methods, the basic supply chain is the same:

1. Production of the biomass feedstock

2. Harvest and storage of the feedstock

3. Transport of the feedstock to a biofuel production facility

4. Conversion of biomass to biofuel and co-products

5. Distribution of biofuel to gasoline blenders

6. Distribution to fuel stations for sale to end user

This section will examine how the various biomass feedstocks follow this supply chain and future problems that must be overcome.

Food-based biofuel. Food-based biofuels use feedstocks that can be eaten or fed to livestock. Because of this, biofuels that use food-based feedstocks are in direct market competition with consumers. This is often used as an argument against food-based biofuels and will be discussed further later in the paper.

Corn-based ethanol. The most common food-based biofuel is ethanol made from cornstarch. This method of producing biofuels has been used for over 30 years and is relatively established compared to other biofuel production methods. The feedstock for cornstarch ethanol is corn and can be produced nationwide, however most corn production takes place in the Midwest (USDA-ERS, 2010). In 2010 the United States produced 12 billion bushels of corn, of which approximately 40% was used to produce ethanol (USDA-NASS, 2010; RFA, 2011b). To convert corn to ethanol the starch must be separated from the proteins. To accomplish this, corn is ground into meal, and enzymes are used to hydrolyze the starch into glucose (Schweitzke et al. 2008). This glucose can then be fermented using yeast to create a mash. This mash is then distilled to separate the ethanol from other liquids. The estimated ethanol yield is 112 gallons per dry ton of corn (Patzek, 2006), however the average yield achieved by US ethanol plants is 100 gallons per dry ton (Mueller, 2010).

The left over proteins, oils, minerals and fibers that are separated from the starch in the corn are used to create a co-product called dried distillers grains with solubles (DDGS). For every bushel of corn that is used to make ethanol, approximately one third of a bushel of DDGS is produced (Nichols et al., 2006). The ethanol producer sells the DDGS to livestock producers as a corn replacement in feed. Because the DDGS are high in proteins and minerals, they help in the production of livestock and are priced to compete with corn for feed.

Following the production of ethanol, the fuel must be transported to a blender. Because ethanol is soluble in water, it cannot be sent current petroleum pipelines and must be carefully stored and transported to limit water contamination. The current method of transport is through rail cars, barges, and over-road trucking (USDA-AMS, 2007). After ethanol is blended with gasoline it uses the same distribution system as gasoline to reach fueling stations where it is sold to the end-user.

Vegetable oils and animal fats. Vegetable oils such as palm seed oil, rape seed oil, and soybean oil, and rendered animal fats are used to produce biodiesel. In the United States soybean oil is the largest biomass feedstock used for the production of bio-mass based diesel due to its use in crop rotation with corn. The production of soybeans is very similar to corn and uses nearly identical storage and distribution systems.

In order to convert soybeans to biodiesel, the oil must be first removed. The soybean is ground into a powder, and a solvent is used to remove the oil from the solids (NSRL, 2010). Once the oil is removed and filtered, a catalyst is used to convert triglycerides into biodiesel. A thermochemical process can be used to refine the biodiesel into green diesel by adding a hydrogenate catalyst (Kalnes et al., 2009). Green diesel made from biodiesel can be used the same way petroleum-derived diesel is used, except that it is solid at room temperature and must be heated for storage, limiting its use.

The current biodiesel production of 532 million gallons uses 16% of all soybean production in the United States (EIA, 2010c; USDA-NASS, 2010). The current production is about half of the mandated level of production in the Renewable Fuel Standard. The total production capacity in the US is 2.7 billion gallons, however low demand due to quality problems limits production (NBB, 2010).

One of the co-products from the production of biodiesel is glycerol, an ingredient in pharmaceuticals and soap production. The solids left from the oil extraction of soybeans produces a high protein meal that can be used as a livestock feed. A biodiesel production facility often receives a better profit from the soybean meal than the actual biodiesel because of a previously established market for soybean meal as a protein additive to livestock feed (Carriquiry and Babcock, 2008).

Due to the cold temperature side effects of biodiesel and green diesel, its blending is limited to ensure the mixture remains liquid. This limitation and relatively small use of diesel as transportation fuel prevent large scale production of biodiesel. Until problems with biodiesel quality are solved production will remain low.

Nonfood-based feedstocks. Nonfood-based feedstocks use a variety of plants and residues that would normally be considered waste. Because these materials are considered waste, a market for their use does not currently exist on a widespread scale and would need to be developed.

Cellulosic feedstocks. Cellulosic ethanol can be produced from a variety of sources, including agricultural residues, forest residues, dedicated energy crops, and municipal solid waste. These feedstocks contain materials comprised of cellulose, hemicellulose, and lignin.

Agricultural residues. During production of crops such as corn, soybeans, and wheat, a large amount of the plant is unused and often discarded in the field to decompose. These unused portions of the plant are referred to as agricultural residues. These agricultural residues are environmentally valuable to the field for erosion control, and their decomposition maintains soil sustainability. The residues are also economically valuable to the producer because they reduce the need for fertilizer. Producers already collect some crop residues from fields for other uses, however collection is very limited.

The most common agricultural residue considered for conversion to cellulosic ethanol is corn stover – the stalk, leaves, and other parts of the corn plant left in the field by a combine harvester. Total dry mass corn stover per acre is estimated to be equal to harvest grain by weight (NAS-NAE-NRC, 2011). With an average yield of 162 bushels per acre in the Midwest, total dry mass is approximately 3.8 tons per acre (USDA-NASS, 2010). Current estimates put harvest of corn stover for conversion between 30-50% of total to maintain sustainability of fields and limit erosion (Beach and McCarl, 2010). At 50% collection, 1.9 dry tons of corn stover could be collected per acre. With corn acreage predicted to be around 90 million acres over the next decade, the EPA estimates 82 million dry tons of corn stover can be harvested (EPA, 2010b).

Forest resources. The Renewable Fuels Standard limits where forest resources can be harvested for biofuel production. Currently trees and tree residues can come only from managed tree plantations grown on non-federally owned lands that were last cleared prior to

December 19, 2007 (110 PL 140). This limit prevents use of many of the most productive forests in the Pacific Northwest which are on federal lands. This limit will force most production to come from the Southeast, where forest plantations are privately owned (NAS-NAE-NRC, 2011). The Energy Independence and Security Act also limits production forests to those planted by humans. This limitation was meant to reduce the clearing of native forests, however new competition for biofuel feedstocks could lead to new plantations on native forestland to meet demand for other wood products. Harvesting of trees for bioenergy feedstocks will remain the same as current tree harvesting systems, however the method of forest residue harvesting is uncertain.

Dedicated bioenergy feedstocks. Several nonfood crops have the ability to be used as bioenergy feedstocks. These perennial crops offer several environmental advantages over their food crop counterparts, but suffer from infrastructure barriers to use. There are several different nonfood crops that can be used as bioenergy feedstocks, but crops like switchgrass, *Miscanthus*, native grasses and short-rotation woody crops are the most popular for future biofuel production (NAS-NAE-NRC, 2011). Until the production of these dedicated bioenergy feedstocks develops into a commercially viable enterprise, the method of production will be unknown.

Municipal solid waste. Municipal solid waste (MSW) made from biological materials such as wood, cotton, and food scraps can be used to produce cellulosic ethanol. According to the Environmental Protection Agency (2010a) the US produced 165 million tons of biological waste that could be turned into cellulosic ethanol. Collection of MSW can be made easier through recycling programs that separate metal, glass, and paper products. There are several barriers to widespread use of MSW for biofuel production. Many urban areas have turned to trash incinerators to produce energy and which would compete with biofuel production (Mann, 1987). In areas where recycling programs are less developed, the process to separate biological materials may be cost prohibitive to producing biofuels.

Cellulosic Supply Chain

Similar to food-based biofuels, the production of cellulosic feedstocks is mostly seasonal and requires large scale storage of feedstocks for use later in the year. Currently the infrastructure for large scale storage and transportation of cellulosic biofuels is limited. Cellulosic feedstocks are far less energy-dense than food-based feedstocks and take much larger areas for storage and transportation. The area required for storage and increased cost of transportation could make unprocessed cellulosic feedstocks uneconomical for use. Regional processing facilities that increase the density of the feedstock through liquefaction could make transport and storage more economical (Carolan et al, 2007). MSW and forest resources do not have these problems because of their availability year around.

There are currently two processes for converting cellulosic feedstocks to ethanol, biochemical and thermochemical (NAS-NAE-NRC, 2011). The two processes both meet the standards required by the RFS for the production of cellulosic ethanol and each has its challenges preventing commercial scale production.

Biochemical production. The current biochemical process for the production of ethanol uses a mix of chemical and biological processes to release the sugars to be fermented. The process is different for each kind of feedstock; this drawback limits what feedstocks a cellulosic ethanol production facility can use, which limits what feedstocks can be grown in the region. The basic process uses chemicals to remove carbohydrates from the lignin and sugars from the cellulose and hemicellulose (Foust et al. 2009). However the current process does not completely remove all of the sugars from the cellulose and hemicellulose. Harsher chemical processes can remove more sugars; however these processes make it toxic for biological fermentation to occur (Olivia et al., 2003). After the mash is fermented, the distillation process follows the same steps as in the production of corn-based ethanol. The solid material remaining from the process can be used as an energy source when burned.

Thermochemical process. The thermochemical process results in a greater number of products than the biochemical process (Spath and Dayton, 2003). Thermochemical conversion of cellulosic feedstocks does not have the same drawback of limited feedstocks as the biochemical process. Several thermochemical processes are being developed to produce biofuels.

Gasification is a thermochemical process that uses high temperature steam and low oxygen conditions to produces syngas from the feedstock (Huber et al., 2006). This syngas is then purified and liquefied and can be used to produce ethanol through fermentation. Alternatively the syngas can be put into a Fischer-Tropsch reactor to produce liquid hydrocarbon fuels that can be added to petroleum fuels. These liquid hydrocarbon fuels are referred to as “drop-in” fuels because they are fully compatible with conventional fossil fuels.

Fast Pyrolysis and Liquefaction are other processes for the production of biofuels. This process uses high temperatures in an anaerobic environment to thermally decompose the feedstock into various hydrocarbons gases. The gas is then condensed into a bio-oil. Currently the bio-oil is incompatible with fossil fuels and needs to be refined for use, but there has been no commercial success in refining the bio-oil to be compatible with fossil fuels (NAS-NAE-NRC, 2011). Liquefaction is a process that also produces bio-oil, but uses high pressure and catalysts to break down the feedstock.

The co-products made from the production of cellulosic ethanol will depend on what processes are used and how much production is achieved. If the Renewable Fuel Standard is met and 16 billion gallons of cellulosic ethanol are produced, the co-products from the production will need to find a market for them to be profitable. The Fischer-Tropsch process has the ability to produce high quality diesel and jet fuel from co-products with proper refining methods. Most of the co-products from cellulosic production are unsuitable for animal feed, unlike food-based ethanol production. However these products are often usable as fuel for boilers and incinerators to produce electricity.

Conclusion

The transportation and distribution of cellulosic ethanol to blenders is the same as corn-based ethanol and suffers the same problems. Due to reporting standards for the Renewable Fuel Standard, there are additional costs to the blender in the form of accounting systems (110 PL 140). Currently very little cellulosic biofuel is being produced in the United States, however there is investment in pilot plants that can be improved to full-size commercial production facilities.

There are several barriers to cellulosic ethanol competing with fossil fuels, including those discussed above. Future technological improvement will decrease the cost of cellulosic biofuels, however it is unknown if these advances will come in time for cellulosic ethanol to meet its mandated production levels under the Renewable Fuels Standard. The current levels of corn-based ethanol and biomass-based diesel production make it believable that those technologies will meet the RFS mandate in time. In order for cellulosic to meet its mandate, the development of new technologies and construction of production facilities must happen quickly, creating large uncertainty as to whether the mandate will be reached.

CHAPTER 2: METHODS

Research Question

The goal of this paper is to examine if current biofuels polices work to meet their goals, determine if these polices have an effect on the biofuels market, or on other markets, and explore what the consequences of those effects are. This paper will also use the conclusions reached from these questions to provide policy recommendations.

Methodology

The paper seeks to complete a literature review on the market effects of federal biofuels policy. The literature review will cover current market effects and possible future effects based on current policy. The literature review will also cover environmental effects, because they are considered a market externality. As a market externality, the cost of the effect is not incorporated in the price of the good, but is hidden. By including environmental effects in the analysis this paper will provide a more holistic look at the market effects of biofuel policy.

CHAPTER 3: LITERATURE REVIEW

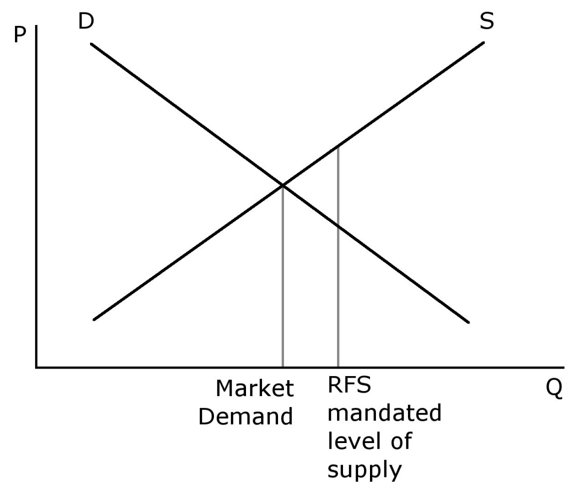
Market Effects

Each of the different kinds of biofuels has different market effects based on various subsidies and how the biofuel is supplied. As mentioned earlier, corn-based ethanol, biomass-based biodiesel and cellulosic ethanol all receive some form of government subsidy that affects the market price of the biofuel.

Market analysis. Biofuels producers rely on various markets, both to sell biofuels and to buy raw materials for their production. Corn-based ethanol and soy biodiesel use preexisting markets for the procurement of raw materials and have well-established markets for the final product. New biofuels such as cellulosic ethanol will have to establish markets for raw materials and meet the standards set to enter the current ethanol market. The mandate created by the Renewable Fuels Standard will force the creation of these new markets and have large effects on other markets. The effects previous biofuel production has had will help in predicting how future biofuels production will affect future markets.

Increased demand for biofuels will affect the supply of the raw materials used to make them. The addition of cellulosic ethanol and its demand for raw materials like switchgrass will change demand for land and what crops are grown on them. Ripple effects will pass through other markets, both domestically and internationally. These changes and their costs may be counter to policy goals. If this is the case, policy options must be explored to mitigate them. There are three main policies that create these market ripple effects; the Volumetric Ethanol Excise Tax Credit, the biofuels import tariff, and the Renewable Fuel Standard. The policy that has the potential for the largest market effect is the Renewable Fuel Standard, because it mandates minimum production levels of biofuels, which has the possibility of not allowing market control of production. If the market demand for biofuels is below the mandated level by the RFS, the RFS is considered binding (Figure 2). If the market

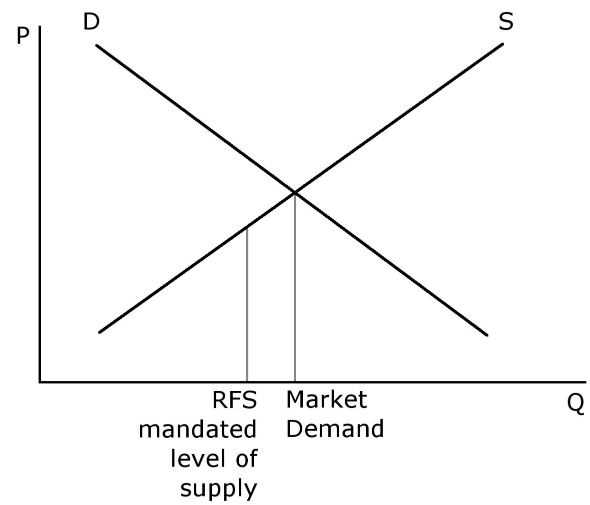
Figure 2: Binding RFS



demand for biofuel production is greater than the mandate, the RFS is not considered binding (Figure 3). For the purpose of exploring how the market is affected by federal policy, this section assumes the RFS is binding, meaning it forces the production of biofuels above the market demand for them.

Biofuel prices. The original intention of the federal blender's credit was to create an incentive for gasoline blenders to mix ethanol with gasoline. While this has created demand for ethanol it has also changed the market. At the previous tax credit of 45 cents per gallon, the market price for ethanol was increased, and with it the profitability for ethanol producers (Babcock, 2008). Increased production of ethanol also requires a larger supply of corn and other inputs; the subsequent increase in demand for inputs raises input prices. There is also an increase in the supply of ethanol co-products such as DDGS. As a result of the tax credit

Figure 3: Nonbinding RFS



and production mandate, there have been far reaching impacts on the biofuel and commodity markets.

In addition to the blender’s tax credit, the federal policy of mandating the supply of ethanol through the Renewable Fuels Standard has an effect on the biofuels market. While the blenders credit has an effect on the biofuels market at all production levels, the RFS only affects the market when it is binding. The RFS mandate for conventional ethanol, which includes ethanol made from corn, tops out at 15 billion gallons in 2015 (110 PL 140). It will be difficult for the ethanol industry to produce more than this amount as the increased price of corn will decrease profitability to levels that hinder investment in ethanol production facilities (Babcock, 2008).

The third part of federal biofuels policy that has had an effect on biofuel prices is the import tariff on ethanol from most countries. The tariff was a 2.5% sales tax on all imported goods in addition to a 54 cent tax on each gallon of ethanol. The imported ethanol is eligible for the blender’s credit, which reduces the cost of the tariff. This tariff creates a price difference between U.S. ethanol and other ethanol sources, including sugar-based ethanol from Brazil. Currently up to 7% of total ethanol consumption imported from several Caribbean and Central American countries is exempt from the tariff, but importers still pay the sales tax. By driving down the importation of cheap ethanol, this policy also artificially increases demand for domestically produced ethanol.

In order to realize how much of an effect past federal biofuels policy has had on the price of biofuels it is vital to look at what the market would look like without the different parts of federal biofuels policy. Bruce Babcock of the Center for Agriculture and Rural Development at Iowa State University ran several economic scenarios in 2008 on how the federal policy affected ethanol and corn production. In the first scenario the RFS was eliminated while the blender's credit and import tariff were kept. Under this scenario the expected ethanol production fell by 4%, which decreased the price by 2%. This scenario has the largest effect on foreign ethanol production as imports decrease by 18%. The removal of only the RFS will only have a small effect on the supply of ethanol because the blender's credit also increases the demand for ethanol.

In the second scenario the import tariff and the blender's credit are ended while the RFS continues. This scenario reflects current federal biofuel policy. By removing the blender's credit, the RFS would be binding; however domestic supply would decrease by 11% (Babcock, 2008). With the removal of the import tariff, the importation of cheaper ethanol from South America would increase by nearly 100% (Babcock, 2008). The decrease in ethanol demand and competition from cheaper foreign ethanol would decrease the price of ethanol by 13% (Babcock, 2008). While the price of ethanol would decrease, the price of gasohol would not decrease because gasoline prices would increase.

The third scenario is the elimination of all three biofuels policies. Under this scenario, total ethanol production would fall by 21%. This decrease in ethanol production would be accompanied by an 18% decrease in ethanol prices due to the artificial increase in price from the blender's credit. Because of the decrease in price of ethanol, imports would only increase slightly.

While federal policies related to biofuels have a large effect on the price of ethanol, oil remains the largest price driver regardless of what incentives may be in place. Because ethanol is a partial replacement of gasoline, its price tends to follow the price of gasoline, which is linked to the price of oil. In turn, corn prices are based on the expected selling price of ethanol. In 2006, the cost of oil was $60 per barrel. This led to a breakeven price for corn of $4.72 per bushel; without the subsidy the price would have been $3.12 (Tyner 2007). Without any federal incentives, a wholesale gasoline price of $3.00 will support ethanol prices of $2.00 and a production of 14 billion gallons, 1 billion gallons below the RFS schedule in 2015 (Babcock, 2008). If oil prices were to drop to a level that would lessen the wholesale price of gasoline, ethanol production and price would decrease. The opposite would occur with higher oil prices.

Commodity prices. In order to understand how biofuel production has affected commodity markets, it is important to understand how the commodity markets have historically acted. The total cropland in the United States declined from its peak in 1981 until 2006 (USDA-ERS, 2007, USDA-NASS 2010). The increase in cropland since 2006 coincides with the first increase in real commodity prices since the 1970s. Prior to 2006 real commodity prices had been decreasing due to increased efficiency, even though demand for corn has increased since 1975 (USDA-NASS, 2010). Between 2004 and 2008 the price of corn, soybeans, wheat, and rice increased by 102% (IMF, 2010). The increases in real commodity prices have a variety of causes, including the increased demand for the production of biofuels, energy costs associated with the production of crops, and increased futures prices. The increase in futures prices can be traced in part to federal policy. As the RFS increased the mandated supply of corn-based ethanol, the corn supply necessary for the expected production increase guaranteed an increase in future demand that speculators could use to expect an increase in corn. As corn-based ethanol production increased, demand for corn went from 10% of total corn production to more than 40% (USDA-ERS, 2010a). This increase in demand has displaced other crop acres to increase the supply of corn to meet the demand of other users, such as livestock producers. Even with the increase in demand for ethanol, the amount of corn fed to livestock has not decreased, since corn yields have increased (USDA-NASS, 2010). Additionally, dried distillers grains with solubles have been used to supplement livestock feed to meet increased demand for livestock production. Further increases in ethanol production to meet the RFS will continue to affect the demand for corn and increase corn prices. If the RFS were to be repealed the price of corn would decrease by a little over 1%; however, if the RFS is fully implemented the price will increase by 3 to 5% by 2022 (Babcock, 2008, Gehlhar et al., 2010).

Increased demand for corn and soybeans have been met through increases in yield; however, future increases in yield are not expected to be as high, which means more acres must be used to produce crops. This increase in cropland for the production of corn and soybeans creates competition for land use. One of the largest competitors for corn and soybean cropland is wheat. The change in land use from wheat production to corn and soybean production will decrease total wheat production and increase wheat prices. While cropland used to produce wheat has continued to decline since 1981, an increase in wheat prices will increase the cropland used to grow wheat, most likely from acres that are unsuitable for corn and soybean production (USDA-NASS, 2010). The allocation of resources used to grow corn, soybeans, and wheat has been for the most part market mediated. Some subsidies have made corn and soybeans more profitable to grow than wheat; however, the increased demand for corn caused by biofuels supported by federal policy has been the largest change that is not purely market based.

The price of corn is now tied to the price of oil due to ethanol (Babcock, 2008). Because ethanol is priced on its energy value in relation to oil-derived gasoline, the price ethanol producers can pay for corn is linked to the price of oil. This connection will continue until other alternative fuels are developed that do not rely on agricultural commodities as raw materials. With the current production capacity in the United States, ethanol with or without federal incentives will continue to be used as a fuel additive for the foreseeable future. If the RFS, blenders credit, and import tariff were all ended, the price of corn would decrease by 13% and similar decreases in other commodities would follow (Babcock, 2008).

Feedstocks such as agricultural residue, forest residue, and dedicated bioenergy feedstocks do not currently have markets to determine their market prices. This lack of information makes analysis difficult to accurately determine the full effects caused by cellulosic production. The National Academy of Sciences (2011) has released a report on its Biofuel Breakeven model, which compares the price biofuel producers are willing to pay and the price cellulosic feedstock producers are willing to accept to try and develop an estimated market price for cellulosic feedstocks. This model provides a basic understanding of where cellulosic biofuel markets may develop and at what prices. The model ignored the Renewable

Fuel Standard mandate and tried to use purely market conditions. Under this model, no cellulosic feedstock had a feasible market assuming an oil price of $111 per barrel and a production efficiency of 70 gallons of ethanol per dry ton of feedstock. At an oil price of $191 per barrel, the market for cellulosic ethanol is feasible; however, what minimum oil price is required to make the market feasible is unknown. There is currently a $1.01 tax credit available for the blending of cellulosic ethanol, but the tax credit is set to expire at the end of 2012, and unless extended, it will not be available to producers of cellulosic ethanol to improve feasibility. While the market feasibility for cellulosic ethanol is questionable, the Renewable Fuel Standard requires its production in order to be blended and will transfer the high cost of production to consumers through high fuel prices. If blenders choose to not blend cellulosic ethanol due to high prices, the penalty for not meeting the RFS would also be passed on the consumer through higher fuel prices.

Grain exports. The U.S. plays an important role in the world market because it has historically been a net exporter of crops like corn, soybeans, and wheat. The demand for corn exports has been fairly constant; additionally, soybean exports have increased and wheat exports have decreased over the last 25 years (USDA-FAS, 2010). One of the reasons that foreign demand for grain has remained stable is due to a decreasing value of the dollar that began in 2002. As the value of the dollar dropped compared to other currencies, the increase in commodity prices was proportionally less. The continued demand for exports and increasing commodity prices has had an effect on market prices, which affects what crops farmers plant in order to maximize profits. In addition, the increase in biofuels production and continued exports have decreased excess supplies that make up the U.S. stocks to use ratio, a metric comparing inventory to expected use. As developing nations' diets change to include larger proportions of meat, the demand will undoubtedly increase competition between biofuels production and exports (Roland-Holst, 2010). By 2015 the price of corn is expected to rise 12.6% from 2010 prices due to total demand increases (Taheripour et al., 2010).

Land prices. Biofuels production will elevate land prices for two reasons: Increased commodity prices raise the profit per acre, which makes cropland more profitable compared to other uses such as pastureland; additionally, the RFS mandate will require more land to grow bioenergy feedstocks. This will increase land prices in areas suitable for bioenergy feedstock production. For current conventional biofuels, such as corn-based ethanol, the required land area will increase by very little and eventually decrease as corn yields improve; however, higher prices will increase corn production. Various techniques such as GPS planting and increased plant populations will result in higher production without the need for more land.

The largest factor in how much land prices will increase due to the RFS will be what source cellulosic ethanol comes from. If dedicated bioenergy crops, such as switchgrass, are used to meet the RFS mandate, a significant increase in cropland will occur. In order to harvest the necessary dry tonnage of bioenergy feedstock, an additional 27 million acres of cropland will be necessary (USDA, 2010). The RFS requires that any land used to produce bioenergy feedstocks be in production prior to December 19, 2007 to prevent land use change (110 PL 140). In order to meet this requirement, production of bioenergy feedstocks will displace 6.5% of cropland, and these displaced crops will require new cropland to meet demand. These crops will most likely be grown on land not previously in production, thereby negating the prior-use requirement.

Until cellulosic ethanol production reaches commercial scale and markets for its feedstocks are established, it is difficult to determine how much land prices will rise. If large amounts of crop and forest residues are used instead of switchgrass, the amount of new land needed could be minimal. But any change in land use will result in some increase in land prices.

Food prices. Commodities' largest use is food production. The increase in commodity prices over the last decade from near all-time real price lows to near all-time highs has contributed to rising consumer food prices (Babcock et al, 2010). According to the USDA, the Food Consumer Price Index increased 4% in 2007 and 5.5% 2008 compared to a historic average of 2-3% (USDA-ERS, 2011b). The near doubling of commodity prices over the same period has had an effect on food prices here in the U.S. and around the world (IMF, 2010). The most important commodity in the relationship between biofuels production and food prices is corn.

It is important to examine how federal biofuels policy will affect corn prices because corn is a raw material used in many foodstuffs and as feed for livestock that produce meat, dairy, and eggs. Increased corn prices caused by rising oil prices and ethanol demand have increased the cost of raising livestock. Raising poultry, which require the largest proportion of corn in their diets, has become 15% more expensive, and very little of that increase has been passed on to the consumer (Tyner, 2007). Eliminating the three major biofuels policies would reduce costs for livestock producers by 7% for beef, 5% for pork, 3% for dairy, and 4% for eggs (Babcock, 2008). Current estimates suggest that a 30% drop in corn prices will lower consumer food expenditures by 1.3%. Corn prices would be even higher if not for the use of DDGS by livestock producers. One bushel of corn is able to produce 2.79 gallons of ethanol and 18 pounds of DDGS (Taheripour and Tyner, 2010). Because it can be used as a corn replacement, its price follows that of corn. Federal biofuels policy has had little effect on consumer food prices, and ending these policies will have almost no effect in lowering food costs.

The reason food prices do not rise and fall at the same rate as commodity prices is due to the processing costs associated with transforming raw commodities into food found on grocery store shelves. The more a product is processed, the less its price is affected by commodity prices. The commodities used to produce biofuels, such as corn and soybeans, require a great deal of processing before they are consumed, and thus are barely affected by changes in commodity prices. The price of corn flakes, for example, is 95% processing costs. A 40% increase in the price of corn would only increase the price of corn flakes by 2%. The average processing costs of U.S. agricultural commodities is 81% (USDA-ERS, 2011c). Due to this high percentage, biofuels currently have a minimal effect on non-meat food prices.

However, changes in commodity prices do have a larger effect on meat prices. Products such as beef, chicken, and pork are more affected because of the feed costs associated with raising the animals. With chicken, the feed, most of which is corn, makes up 69% of the cost of bringing the meat to market (Donohue and Cunningham, 2009). In addition, the length of time to market plays a large factor. Broiler chickens are raised in short time period measured in weeks, whereas cattle raised for beef require up to two years from birth to slaughter. The longer period for which feed must be fed increases the cost caused by increasing commodity prices. Due to the various techniques used to raise livestock for slaughter it is difficult to determine how much of the increase in meat prices is due to biofuels production. The best metric to use to determine the effect of biofuels is to look at the price of chicken, as most broilers are raised in a uniform way. Of the total price of chicken, 42% goes to raise the broiler, of which 69% is feed, in this case corn—meaning of the increase in chicken prices, 5.8-11.6% was as a result of increased commodity prices (NAS, 2011). The increase in meat and dairy prices will have some effect on demand for those products.

In addition, the increased cost of raising livestock affects more than just food prices. Co-products from meat production such as leather and wool will also be affected. Taheripour et al. (2010) predicted that between 2006 and 2015, the worldwide decrease in livestock industries would equal $3.7 billion. But most of the contraction occurring in countries that still rely on corn for feed instead of DDGS. Within the United States, the contraction of the livestock industry is projected to be $0.9 billion.

Biofuels will also affect how livestock are produced. Increased grain prices will cause an increase in the use of pastureland as cropland. Taheripour et al. (2010) estimated that 18.7 million acres of pastureland could be converted to cropland by 2015 due to increased grain prices. This reduction in pastureland will change how livestock are raised; including a possible increase in concentrated animal feeding operations such as feed lots and hog confinements.

Oil and transportation fuels. If the RFS is achieved and 36 billion gallons of biofuels replace fossil fuels, total U.S. demand for oil will drop by 9.5% (EPA, 2010b). This reduction in oil usage will reduce worldwide oil demand enough to decrease the price of a barrel of oil by as much as $1.05. Other studies show that the worldwide price of oil would fall by approximately 4% and standard gasoline prices would decrease by 8% (Gehlhar et al., 2010). The price of gasoline sold as transportation fuel would decrease by 12% because it would be blended with less expensive biofuels such as ethanol.

If the RFS is fully implemented and fuel efficiency standards are met, the amount of oil imported for transportation fuel will decrease. USDA-ERS (2010b) predicts that the use of biofuels will reduce oil imports by 16-17%. This reduction will lower US oil import expenditures by $61-68 billion. This decrease in imports would cause the dollar to appreciate and reduce the cost to import other goods. An increase in the value of the dollar would also reduce exports to other countries.

The RFS is a consumption mandate that requires the blending of various renewable fuels. While fuels like corn-based ethanol and soy biodiesel are price competitive with gasoline and diesel, cellulosic ethanol is not. If the price of cellulosic ethanol remains high and the tax credit is allowed to expire, the high cost will be passed onto the consumer because of the consumption mandate. This increase in transportation fuel price would cause a reduction in demand for transportation fuel.

Conclusion. Understanding the market effects of biofuels policy is important in determining the effectiveness of the policy. Current biofuels production has had multiple market effects and the future production of cellulosic biofuels could have major market effects. While the actual market effects of cellulosic ethanol are unknown, the predictions leave pause. Federal policy has been designed to reduce land use change; unfortunately, markets will undoubtedly cause land use change that has repercussions beyond the market. Even though biofuels have had minimal effects on food prices in the United States, future biofuel production could have larger impacts as food crops compete for land. The effects on food prices will also be much more dramatic in underdeveloped countries.

Effects on Federal Revenue and Expenditures

Federal biofuels policy also affects federal revenues and expenditures and has a broad range of impacts in areas including tax revenues, welfare programs, agriculture support programs, and conservation programs.

Federal revenues. Federal biofuels policies both add to the federal coffers and take from them. The major policies that affect federal revenues are the blender's credit, the import tariff, and federal income taxes.

Volumetric Ethanol Excise Tax Credit. The volumetric ethanol excise tax credit, also known as the blender's credit, has had a large effect on tax revenue because it reduces the amount owed by blenders. The VEETC was allowed to expire at the end of 2011. In 2010 the 45 cent tax credit for corn-based ethanol reduced tax revenues by nearly $5.4 billion (GAO, 2011). The blenders credit also has a subsidy for cellulosic ethanol of $1.01 per gallon; however, the tax credit is set to expire in 2012 and no commercial facilities are expected to be operational in order to receive it. While the blender's credit expired at the end of 2011, it can be renewed retroactively, though this is unlikely. If the tax credit were extended, at the RFS mandated supply of 15 billion gallons annually the blender's credit would reduce federal revenues by $6.75 billion per year (GAO, 2011).

Import tariff. In addition to the VEETC, the government has previously laid an import tariff of 54 cents per gallon plus 2.5% of the import value. In total, the tariff brings in around 59 cents per gallon of imported ethanol. This tariff also expired at the end of 2011. The imported ethanol was also eligible for the blender's credit, which withholds tax revenues at 45 cents per gallon. This leaves approximately 14 cents per gallon in federal revenue per gallon of imported ethanol. Even without the tariff, current corn-based ethanol production makes it unlikely that any ethanol will be imported to fulfill the conventional biofuel portion of the RFS. Because most imported ethanol is made from sugarcane, it is possible for it to fulfill the advanced biofuel requirement.

Income tax revenues. The increases in commodity prices have helped to increase on-farm incomes, which have resulted in increased income tax revenues. Net farm income for 2010 was $79.1 billion, up from $61.6 billion in 2009 (USDA-ERS, 2011d). The USDA forecasts that 2011 incomes will increase by 31%. Unfortunately, how much tax revenues have increased is unknown because the most recent data on tax revenues from farm activities is from 2004 (USDA-ERS, 2009).

Federal expenditures. There are several federal policies that could be affected by the biofuels production. Currently several programs are set up to provide subsidies for the production of corn and soybeans. Welfare programs, such as food and nutrition assistance, will costs more due to higher food prices caused in part by biofuels production. Federal programs for the construction of biofuel production facilities directly subsidize biofuel producers. There are also some social costs associated with the production of biofuels that affect federal policy.

Cellulosic ethanol production facility construction programs. There are several programs that provide money to help pay for the construction of cellulosic ethanol production facilities. These programs take the form of tax credits, grants, loans, and loan guarantees. Programs range from $50 million up to $400 million per construction project. Programs like these are direct federal expenditures on biofuels production, unlike other expenditures discussed below.

Farm programs. The Food, Conservation, and Energy Act of 2008, better known as the 2008 Farm Bill, renewed several programs that were established to help support low commodity prices (110 PL 234). The 2008 Farm Bill authorized three programs to help farmers through direct payments, countercyclical payments, and loan deficiency payments. With the current prices of commodities, these programs are unnecessary, and biofuels policies increase the expenditures of some of these programs.

The direct payment program pays farmers a fixed amount for producing certain kinds of crops. Among the eligible crops are corn and soybeans. As corn-based ethanol production has increased, the supply of corn necessary to meet demand has jumped which increases the funds required to make direct payments—no matter what the market prices for those eligible crops are. The 2008 Farm Bill established direct payments at 28 cents per bushel for the 2012 crop year. The Farm Bill is set to be renewed in 2012, which could change the direct payment schedule, though reauthorization will most likely be delayed due to the 2012 elections.

The government also provides countercyclical payments if the market price of an eligible crop falls below a target price. Biofuels policies have helped to increase the market prices for eligible crops. Under the Farm Bill, the target price for corn is $2.63 per bushel. At the time this paper was written, the market price for corn was $6.59 minus basis cost (CME, 2011). Because the current price is more than double the target price, no countercyclical payments have been made. Due to the current market price and projected market price without biofuels policies, the federal expenditure is expected to be zero; however, federal biofuels policy does not ensure this, so it does not save the federal government any money by keeping the policy.

The final program authorized by the Farm Bill provides loan deficiency payments meant to assist farmers in meeting operating loans if the market prices of eligible crops fall below the market loan rate. The Farm Bill set the marketing loan rate at $1.95 per bushel of corn. Under this program the government will pay farmers the difference between the market price and the marketing loan price if the market price is below the marketing loan price. Similar to countercyclical payments, biofuel policy does not help to keep the market price above the marketing loan rate, nor does it push the price below it.

Based on USDA (2011) projections for 2011-2021, the prices of corn, soybeans, and wheat will not fall below any of the target prices or marketing loan rates. Because of this, the government is unlikely to make any countercyclical payments or loan deficiency payments. However, federal biofuels policy does nothing to ensure that prices do not fall below these levels. Instead, the policies have increased the demand for corn and soybeans, and thereby increased the funds necessary to meet direct payment obligations.

In addition to programs to support commodity prices, the Farm Bill reauthorized several conservation programs, including the Conservation Reserve Program (CRP), which was developed to help conserve high-risk acres that were in agricultural production by paying farmers to remove them from production. The 2008 Farm Bill allows 32 million acres to be enrolled in CRP. In 2010, 31.3 million acres were enrolled in CRP on 10-15 year contracts that paid an average of $44 per acre. To qualify for CRP, the land had to be used to plant an agricultural commodity for four of the previous six years (110 PL 234). As biofuel production expands, the demand for land to grow bioenergy crops for both cellulosic and conventional biofuels will increase. Due to the requirements to enroll in CRP, that land will fulfill the land use change requirements of the RFS. In order for CRP to compete with possible biofuels profits, it will have to increase its per acre payment. In 2010, CRP cost $1.7 billion, and that figure will likely increase (Cowan, 2010). In recent years the number of acres applying for CRP has been higher than the number of acres available to be enrolled; however, new bioenergy crops could be better suited to grow on some marginal CRP land that was unprofitable for corn or soybean production. Currently, bioenergy crops such as native grasses or switchgrass cannot be harvested from CRP land. If this rule changed it could be possible for CRP enrollments to stay high at reduced rates by allowing bioenergy crops that are suitable for conservation purposes to be grown and harvested for use in the production of biofuels.

Nutrition and income assistance programs. One of the market effects discussed earlier is the increase in food prices caused by federal biofuels policy. While the increase due to biofuels is small, the increase affects low-income groups the most, especially those relying on government nutrition and income support. Programs like the Supplemental Nutrition Assurance Program (SNAP) and the Special Supplemental Assistance Program for Women, Infants, and Children (WIC) provide financial assistance to help low-income families buy food. Annually the Food Consumer Product Index (FCPI) increases by 2-3%, however, when global food stocks are low, such as they were in 2006-2008, food prices increase faster than average. Spending on programs like SNAP and WIC is linked to increases in the FCPI. According to Congressional Budget Office (2009), FCPI increases associated with biofuels resulted in a boost in SNAP funding of $500-800 million and in WIC funding of $75 million. As food prices are expected to increase, in part due to increased production of biofuels, the federal expenditures for SNAP and WIC will have to increase to compensate.

Supplemental income programs, such as Social Security, Supplemental Security Insurance, and military and federal retirement programs, increase payments with increases in the total Consumer Price Index. In 2009, Social Security and Supplemental Security Insurance had a combined budget of $709.6 billion and increases every year. The massive size of these programs causes even small changes in the CPI caused by biofuels policy to increase federal expenditures in huge proportions.

Social costs. In addition to federal expenditures that can be quantified, there are social costs caused by market failures that could increase the cost of federal biofuels policies. One of the largest social costs is the environmental impact of biofuels production and use. This topic will be discussed further in its own section. Other social costs include the transformation of the agricultural industry from small family farms to large corporate farms due to increased costs associated with operating a farm. This could affect federal programs designed to increase small farms (110 PL 234). Social costs, while hard to quantify, should play an important part in analyzing the effectiveness of biofuels policy.

Environmental Impacts of Biofuel Policy

In an effort to reduce the environmental impact of fossil fuels, the U.S. has added biofuels to transportation fuels to make them burn cleaner and to decrease greenhouse gas emissions. In recent years the actual environmental benefit of the use of biofuels has been questioned. While the addition of biofuels does make a fuel burn cleaner, growing bioenergy feedstocks and producing biofuels requires the use of fossil fuels and other resources that may become unsustainable (Robertson et al., 2008).

In order to understand their impact, it is important to look at recent life-cycle analyses (LCA) that evaluate the environmental impact of biofuels production. It is important to understand any negative environmental externalities associated with biofuels production in a market analysis, because the externality is considered a market failure. The emissions from biofuels must also be compared to the emissions from fossil fuels to determine if the policy goals of the Renewable Fuel Standard are being met.

Life-cycle analysis. A life-cycle analysis looks at the production of biofuels from the very beginning until the end consumer burns the fuel (ISO, 2006). The LCA must begin with land use change, examine the production process of growing bioenergy feedstocks, the infrastructure related to the transportation and storage of bioenergy feedstocks, the biofuel production process, the blending process, and the emissions from the consumption of the biofuel.

Environmental effects. In order to understand the environmental impact of biofuels, multiple factors must be examined: Greenhouse gases, air pollutants, soil sustainability, water quality, and water consumption all must be reviewed.

Greenhouse gas emissions. The International Panel on Climate Change defines a greenhouse gas as:

> A gas that absorbs radiation at specific wavelengths within the spectrum of radiation (infrared radiation) emitted by the Earth's surface and by clouds. The gas in turn emits infrared radiation from a level where the temperature is colder than the surface. The net effect is a local trapping of part of the absorbed energy and a tendency to warm the planetary surface. Water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. (IPCC, 2011)

Biofuels both consume and release various greenhouse gases throughout the production process; however, the net effect is different for each of the bioenergy feedstocks and production processes. Without knowing what feedstocks will be used to produce cellulosic biofuels in the future, the exact amount of greenhouse gas emissions will be unknown. That said, studies of the different production possibilities give a good prediction of how much could be emitted.

One of the largest greenhouse gas emissions related to biofuels production is caused by land use change. The transfer of land from native ecosystems to row crop-farms increases the level of GHG emissions compared to using land previously in production (Fargione et al., 2008). With rising commodity prices, there has been an increase in the number of acres planted, leading to market-mediated land use change, which could release carbon stored in the soil and vegetation planted there. If the production of cellulosic ethanol becomes a reality, the new market for cellulosic feedstocks will introduce an additional competitor for land use and could increase the acres farmed in the U.S. Biofuels policies also have the ability to affect global land use. The Global Trade Analysis Project estimated that for every 1,000 gallons of corn-based ethanol produced, there would be a land use change of 0.32 acres, which would result in over 5 million acres of land use change if the 16 billion gallons required by the RFS is met (Tyner et al., 2010). The land appropriated by biofuels production would be 33% forest and 67% pasture and grassland. In order to combat land use change Congress required that all biofuels feedstocks be grown on land in production before December 19, 2007. However, bioenergy feedstocks could be grown on land already in production and the previous crop moved to new land. Because of this, it is very difficult to enforce the regulation (111 PL 140). Converting forest to cropland releases a large amount of carbon (NRC, 2010a). For this reason it is important to limit how much land use change occurs due to biofuels policy.

The type of bioenergy feedstocks used to produce biofuels plays a big role in determining GHG emissions. Perennial crops have a higher carbon sequestration potential than annual crops; some crops require fewer agricultural inputs made from fossil fuels, and equipment requirements for production (Anderson-Teixeira et al., 2009). While annual crops like corn and soybeans require greater inputs, they are converted to biofuels more efficiently than perennial cellulosic feedstocks, which reduces the emissions per unit of fuel, even though emissions are higher per unit of land (Williams et al., 2009). Corn and soybeans also have an advantage over cellulosic feedstocks in that very little, if any, land use change is needed to produce enough feedstocks to fulfill the RFS.

The inputs and management practices for growing bioenergy feedstocks also affect GHG emissions. Several studies have compared the carbon storage of different soil management practices, including no-till and conventional tillage. These studies found no difference in carbon storage between the different tillage methods; however, conventional tillage does require tractors to till the soil, which release carbon (Blanco-Canqui and Lal, 2008, Christopher et al., 2009). Bioenergy feedstocks can require large amounts of agricultural inputs depending on the soil used to grow them. Fossil fuels are used to manufacture agricultural inputs like fertilizers, herbicides, and pesticides, which must then be transported and applied (Snyder et al, 2009). Nitrogen fertilizer releases nitrous oxide in its production process and through nitrification of soil after application to fields, both of which increase GHG emissions (Bouwman et al., 2010). The EPA (2010c) estimates that 68% of all N_2O emissions come from agriculture. Better management practices can reduce GHG emissions by requiring fewer inputs; however, they require educating farmers.

The production process used to turn feedstocks into biofuels also has significant GHG emissions. Carbon dioxide is released in the fermentation process that turns sugars into alcohol. Ethanol plants use fossil fuels or burn biomass to create heat and electricity required for production (RFA, 2011). Carbon emissions from burning biomass are considered carbon neutral, because biomass releases carbon already captured from the atmosphere. Few production facilities use this method, though as cellulosic production facilities are being built, planners are choosing to move to biomass in order to be more carbon neutral (Wang et al., 2011a).

No matter what bioenergy feedstock or production process is used, once the ethanol is produced, the transportation and tail pipe emissions are the same. Once the GHG emissions are measured or estimated, a LCA can be completed. Because each kind of biofuel mandated by the RFS has a different GHG emission standard, separate LCAs must be done for each fuel type.

Searchinger et al. (2008) conducted a U.S. average life-cycle analysis of corn-grain ethanol that puts total GHG emissions at 177 g CO_2 eq per MJ, compared to gasoline, which has life-cycle GHG emissions of 49 g CO_2 eq per MJ (Hsu, 2011). Of all the cases examined, the Searchinger et al. study had the highest GHG emissions; Wang et al. (2011a) had the lowest GHG emissions at 69 g CO_2 eq per MJ. These studies, however, did include carbon emissions from land use change that has already occurred to determine the life-cycle carbon emissions. Because the land use change has already occurred, ending the use of corn-based ethanol will not decrease GHG emissions. The EPA in its final rulemaking for the Renewable Fuel Standard conducted its own LCA and determined corn-based ethanol did meet the 20% reduction of GHG emissions compared to gasoline to fulfill the mandate (EPA, 2010b).

Biofuels made from municipal solid waste and agricultural or forest residues have a far better opportunity to reduce GHG emissions compared to corn-based ethanol. This is in large part because there is very little land use change involved if sustainable amounts of residues are removed (Cherubini and Ulgiati, 2010). MSW has the largest opportunity to reduce GHG emissions; however total volume of waste can only produce enough biofuels to replace 2% of fossil fuels used for transportation (Kalogo et al., 2006).

The GHG emissions caused by future use of dedicated bioenergy crops to produce cellulosic ethanol depend on what land use change occurs. If the production of dedicated bioenergy crops causes land use change either directly – or indirectly, as farmers seek land to grow displaced crops – the life-cycle GHG emissions could increase enough to cause the biofuel to not meet RFS requirements (Roberts et al., 2006). The land used to grow dedicated energy crops must have a low carbon sequestration ability in order for the GHG emissions to be low enough from the land use change. While the GHG emissions may be higher than allowed by the RFS, GHG emissions from land used to grow dedicated bioenergy crops will be lower than if used to grow corn or soybeans for biofuel production (Hammerschlag, 2006).

While the EPA has determined corn-based ethanol to fulfill the necessary GHG emissions reduction, other studies show it does not meet the standard, leaving definitive conclusions open to further research. Biofuels produced from MSW and agricultural or forest residues have been shown to reduce GHG emissions enough to meet the RFS standard, however it is unknown if enough supply to produce the required amount of biofuels can be obtained without negatively affecting soil sustainability. As far as the amount of GHG emissions from cellulosic ethanol, the variability of production methods makes it difficult to determine if the biofuel will meet the RFS standard. As more research is conducted into GHG emissions and cellulosic ethanol becomes commercially viable, it will be possible to determine if cellulosic ethanol meets the RFS standards.

The Renewable Fuels Association, a public policy organization promoting the use of ethanol and other biofuels, lists several facts about ethanol and its effect on the environment. It specifically cites a study by Liska et al (2008), which found a life-cycle GHG emission reduction of 48-59%. The study found this reduction by only looking at the most efficient of biorefineries and crop planting systems, and ignoring historical averages. While this study does do a good job of finding what the most efficient systems are capable of, it ignores the real-world production that exists. A majority of biorefineries are far less efficient than the ones examined in this study, and the corn production methods are not easily changed on a nationwide scale to meet the most efficient practices. While the study is useful to show what the future of biofuels production could be, it is unlikely that the industry as a whole will ever reach this efficiency before the RFS expires.

Air quality. In addition to GHG emissions, biofuels also emit various air pollutants, including: carbon monoxide, sulfur dioxide, nitrous oxide, particulate matter, ozone, ammonia, and volatile organic compounds (VOCs) (NAS, 2009). These air pollutants can harm to humans and the environment. Hill et al. (2009) compared the emissions of these air pollutants for the different biofuels and also for gasoline production. The study determined that ethanol made from either cellulosic or corn feedstocks resulted in higher emissions of VOC's, nitrous oxides, ammonia, and particulate matter than gasoline; cellulosic ethanol emitted lower sulfur dioxide emissions than gasoline, while corn-based ethanol emitted higher.

Air pollutants are much different from GHG emissions, because their effects are local rather than worldwide. As discussed earlier, ethanol was used as an oxygenate to meet Clean Air Act requirements for certain urban areas, because the problems are local rather than widespread. Because air pollutants are a local problem it is difficult to quantify the issue at the national level. In areas with poor air quality, biofuels will make the problem worse. Cook et al. (2011) determined that air pollutant emissions caused by the RFS would be 11 million tons of nitrous oxide, 47 million tons of carbon monoxide, 9 million tons of sulfur dioxide and 4 million tons of ammonia. The EPA (2010a) determined that due to these increased air pollutants, up to 245 premature adult deaths could occur.

Soil sustainability. Soil sustainability is the ability of soil to retain nutrients required to grow crops. Current agricultural practices include, crop rotations, nutrient application through fertilizer, and natural decomposition, which help ensure soil sustainability. Soil tests are capable of determining if soil has the proper nutrients to stay sustainable. Improved management practices can help ensure soil sustainability. One of these practices is allowing agricultural residues to decompose into the soil; however, one plan for increasing biofuels production removes large amounts of agricultural residue and would require shifts in management practices to make up for the lost nutrients. Additionally, certain bioenergy feedstocks help the soil complete the nitrogen cycle and would improve soil sustainability.

In order to produce cellulosic biofuels from agricultural residues, the residue must be removed from the field, which reduces the material that would naturally decay to replenish soil nutrients. It is important that too much agricultural residue not be removed from agricultural fields to ensure soil sustainability (Huggins et al., 2011). As more residue is removed, more nutrients must be added to maintain sustainability.

Agricultural irrigation also has a unique effect on soil sustainability. Water from aquifers often contains minerals that are left in the soil after the it evaporates. These minerals increase soil salinity, which reduces yields (El-Ashry et al, 1985). Nearly half of all irrigated soil is affected by salinity that reduces crop yields (NAS, 1993). As more irrigation is used, soil salinity will increase and eventually make the soil unusable.

Water quality. Increased biofuel production that causes land use change will have an effect on water quality. Water quality will be most affected by the increase in biofuels production if land that was not in production is planted with crops that have little ground cover (Engel et al., 2010). Poor ground cover increases erosion and runoff of chemicals and fertilizers, which can cause water quality problems at great distances.

One of the most studied water quality problems related to runoff is the hypoxia zone in the Gulf of Mexico caused by excess nitrogen from Mississippi river basin (Dale et al., 2010b). A hypoxia zone is an area that lacks enough oxygen in the water for organisms to survive. Excess nutrient runoff has been attributed to the increasing size of the hypoxia zone in the Gulf of Mexico (Liu et al., 2010). Large hypoxia zones reduce profitability for fisherman and shrimpers.

As biofuels production increases and more land is used to produce bioenergy feedstocks, the amount of runoff will increase with it (NRC, 2008). The increase in runoff will depend on what bioenergy feedstocks are planted. Perennial crops such as switchgrass allow less erosion and runoff compared to annual crops like corn. If cellulosic ethanol is made from agricultural residues, the reduction in land cover will also increase erosion, depending on soil management practices. Unfortunately no LCAs exist that estimate how much water quality is affected by biofuels production (Secchi et al., 2011).

Because biofuel production facilities are required to apply for National Pollutant Discharge System permits, the facilities must meet standards set by the Clean Water Act to ensure water quality from any discharges (88 PL 206). While the production of biofuels results in no water quality problems, the use of biofuel co-products does pose problems for water quality. DDGS contain concentrated amounts of nitrogen and phosphorus that are not digested by livestock, pass through the animals, and are disposed of in the manure. The higher concentrations of nitrogen and phosphorus can cause problems if the manure is used as fertilizer and not adequately diluted (Benke et al., 2010).

As discussed earlier, irrigation has the ability to increase soil salinity. Runoff from saline soil can increase water salinity. Increased river salinity has major consequences for downstream users. Increased salinity of the Colorado River during the 1970s caused Congress to approve funding for a desalination plant to take salt out of the river (93 PL 320). Increases in irrigation for bioenergy feedstocks could cause similar situations in other river basins, including the Mississippi.

Water consumption. Policy makers have long overlooked the amount of water used to grow crops in the United States. Increased reliance on irrigation and land use change can have dramatic effects on aquifers and ground water. Water for the production of bioenergy feedstocks comes from several sources depending on where the feedstocks are grown. In areas like Nebraska and Kansas, farmers irrigate with water from aquifers; in areas like Iowa and Illinois, groundwater replenished through rain provides water; and in areas like southern California, water is diverted from rivers for irrigation (Howell, 2001). As more bioenergy feedstocks are used, more water will be necessary to maintain production.

Much of the crop production from South Dakota down to Texas relies on water from the Ogallala Aquifer. As the amount of land used to produce bioenergy feedstocks increases, the rate of water depletion in the aquifer also increases (Clark and Peterson, 2008). This is an important issue because the production of bioenergy feedstocks can consume water faster than resources can be replenished. Currently agriculture uses one third of all water, and this figure will grow if there is an increase in bioenergy feedstocks. Even if the increase in production comes through higher crop density instead of land use change, more water will still be required.

Increased planting of bioenergy feedstocks in areas that do not require irrigation also has an effect on water consumption. As more crops are planted in areas that rely on groundwater saturation, the level of groundwater can fall below the root zone. Additionally, as groundwater drops, streams, rivers, and lakes will have decreased inflow (USGS, 1999). A streams or river is classified as gaining or losing depending on its relationship with groundwater. Increased use of groundwater could turn streams that were once gaining into ones that are losing, which could affect groundwater downstream. Unfortunately, little research has been completed to quantify how much increases in biofuel production will affect groundwater resources. But there is little doubt that more production will cause decreases in groundwater.

Many of the 31 states that make up the Mississippi river basin are currently cultivated with crops that can be used as bioenergy feedstocks, and will see increases in acres planted as markets for cellulosic feedstocks develop (US Army Corp of Engineers, 2001). As less groundwater is available for discharge into the Mississippi and its tributaries, the water level of the river could drop, hindering commerce that uses the river for transportation.

Decreased water inflow can also reduce the amount of water available for gravity irrigation of other crops. Vegetable production around the Salton Sea in southern California relies on irrigation from the Colorado River (Imperial Irrigation District, 2011). Increases in upstream water use, both in irrigation from the river and decreases in groundwater discharge, could prevent adequate water from reaching southern California. Additionally, the Colorado River flow could have implications in foreign relations. The Mexican Water Treaty of 1944 requires 1.5 million acre-feet of water flow to Mexico annually. While the outflow of water from the Colorado River is tightly regulated, the inflow from groundwater is not and could be affected by future bioenergy feedstock production.

Conclusion

While the environmental impact of producing corn and soybeans has long been studied, how much new bioenergy feedstocks like switchgrass and residues will affect the environment is largely unknown because it's unclear which bioenergy feedstocks will be grown. The production process for cellulosic ethanol is also filled with many unknowns because of the lack of commercial production to study. But from what *is* known about the environmental impact of biofuels production, certain conclusions can be made.

The life-cycle greenhouse gas emissions of cellulosic ethanol will not meet the standards set by the RFS if large land use change is caused. Only if the RFS can be met through means that do not cause land use change will the GHG reduction standards be met. However, the available sources of bioenergy feedstocks that will not cause land use change make this highly unlikely. Increased production of bioenergy feedstocks will have major effects on air quality, soil sustainability, and water quality. In order to better understand how much biofuels will affect these environmental components, more research is needed. Water consumption is one of the most important environmental factors facing the future of biofuels production that has far reaching consequences. Future research is needed into all of these environmental factors; however, what is known now will help develop future biofuel policy.

CHAPTER 4: RESULTS

From the literature review, several conclusions can be made. Federal policy supporting the production of biofuels has been based on two priorities, energy security and environmental protection. The current policy will have little impact on ensuring energy independence, because biofuels are not capable of replacing enough oil-based transportation fuels to end oil imports. There is also doubt that current requirements can be met because of uncertainty in how much greenhouse gases will be emitted from the future production of biofuels; if the policy cannot be met, changes will have to be made.

Policy Problems

The current Renewable Fuel Standard requires 36 billion gallons of biofuels be produced by 2022. Currently the U.S. uses 138 billion[1] gallons of fuel a year. Replacing 36 billion gallons will do little to reduce the total consumption of fossil fuels and will only reduce oil imports by 9.5% (EIA, 2010a; EPA, 2010b). There are also regulatory barriers to achieving the RFS. For instance, the EPA will only allow a 15% blend of ethanol to be used, and the 15% blend can only be used in cars manufactured after 2001. This level of blending will only allow 20 billion gallons to be blended each year (EPA, 2011). Until this regulatory problem can be fixed, the RFS will do little to meet it energy security goal.

In addition to energy security concerns, biofuels have been supported because of their environmental benefits. Current studies that try to measure greenhouse gas outputs associated with the production and use of biofuels do not provide a clear picture of biofuels' benefits or costs. The methodologies of these studies vary greatly and use different data estimations due to the lack of observations. In examining the various methodologies, several questions have

[1] 378 million gallons/day * 365 days = 137,970 million gallons/year

arisen in determining which study best represents reality. How far back in the production chain should we measure greenhouse gas output? Should land use change that has already occurred be included in determining the GHG emissions of the fuel? Are the data estimates accurate enough to provide an adequate measurement?

From the literature review, there is data that suggests corn-based ethanol does not meet the required life-cycle reduction of GHG emissions to be considered for use under the RFS; however, the Environmental Protection Agency has determined that corn-based ethanol does meet the requirements. There is also considerable uncertainty about how cellulosic ethanol will be produced. Without knowing this, a life-cycle analysis that determines the GHG emissions is impossible to complete. While no LCAs exist to measure the possible carbon emissions, some predictions can be made. The land required for the production of bioenergy feedstocks will almost certainly cause land use change that will increase GHG emissions beyond the requirements of the RFS.

In addition to problems with its policy goals, the current Renewable Fuels Standard is unachievable with current technology. The RFS mandates 16 billion gallons of cellulosic biofuel by the year 2022; currently no commercial cellulosic biofuel production facilities exist and the cost to produce cellulosic ethanol makes it highly unlikely that the mandate will be achievable (NAS, 2011). While the mandate for cellulosic biofuels is nearly unattainable, the mandate for 15 billion gallons of conventional biofuels will be easily reached by 2015, as production capacity currently sits at 14.1 billion gallons. The requirement of 4 billion gallons of advanced biofuels poses a challenge, as where the biofuel will come from is unknown.

Currently, demand for corn-based ethanol is higher than the production mandated by the RFS. While the blenders credit did increase demand some, most of the demand is market driven. The production of corn-based ethanol will continue regardless of federal biofuels policy. Because so much of the demand for corn-based ethanol is market driven, any policy changes will have minimal effects on its future.

In addition to the current federal policies not meeting their goals, the policies have some negative market effects that make them undesirable. The development of cellulosic feedstock markets will be costly due to the infrastructure required, especially when considering that demand for biofuels relies on demand for oil; when newer fuels are developed, the demand for biofuels will end, leaving the costly infrastructure for cellulosic feedstocks with no use.

The market effects of corn-based ethanol are much more limited than cellulosic because there exists a demand for corn outside the biofuel industry. The demand for corn-based ethanol is also largely market driven instead of policy driven, and, as such, changes in policy will have little effect on the market.

While federal biofuels policies do have effects on the market, the larger problem is with the policies themselves.

Policy Basis

As discussed earlier, the reasons for federal biofuels policy are based on two main factors, increase energy security and reduce environmental impact. From the results of the literature review it is possible to examine if the policy fulfills the reasons for its existence. With the current ethanol blend cap of 10% for all cars produced before 2001 and 15% for cars produced after 2001, the actual ability of biofuels to reduce oil imports is limited. Even if the production and use of E85 vehicles increases, the impact on oil imports will be negligible until these vehicles make up a larger percentage of total cars. Proponents of biofuel use argue that a 10% reduction saves millions of dollars per day; however, it is unknown whether the reduction in oil use comes from foreign oil imports or domestic production. If the reduction is not in imports, biofuels do not save any money from being sent to exporting nations. The best solution to reducing oil imports is to move to a transportation system that does not rely on oil based fuels, but instead on electric, hydrogen, or some other fuel source.

The environmental implications of biofuel use are much more complex, and the improvements are questionable. Initial studies have reduced tailpipe emissions. However, more in-depth research and full accounting of the environmental impact produces doubt about biofuels' ability to reduce the environmental impact of transportation fuel. More study is needed, however current scientific conclusions fail to show the improvement expected from biofuel use.

With this improved information about biofuels, it is time for a reevaluation of current policy. There is little doubt that the biofuels market will exist until a better alternative is discovered, whether the federal government mandates its use or not. This means discontinuation of any federal policy is a viable option.

Discussion

The ability of current biofuels to meet the policy goals of the Renewable Fuel Standard is questionable. Because of this, it is the recommendation of this paper that the Renewable Fuels Standard be repealed. Biofuels, while successful in reducing fossil fuel demand in the short term, are not a long-term solution to the transportation fuel needs of the United States. With current regulations limiting the amount of biofuels that can be blended and market demand for corn-based ethanol ensuring its continued use, there is little reason for the Renewable Fuel Standard.

The blender's credit provided unnecessary support for biofuels production at a cost to taxpayers. The tax credit has been useful in spurring demand to create the current ethanol industry; however the current political climate of budget austerity will make a future renewal of the credit unlikely. Studies have shown that corn-based ethanol will continue without the tax credit, but because the tax credit has only been absent for a short period of time any actual effect is unknown. For this reason, and considering the current political climate, this paper recommends the blender's credit remain un-renewed. If the blender's credit were essential to the continued production of corn-based ethanol, the recommendation may be different, however that is not the case.

As with the blenders credit, it is the recommendation of this paper that the import tariff also remain un-renewed. Without the blenders credit, the import tariff would make the cost of imported ethanol far too high, and demand would drop to zero. There are also concerns that the import tariff without the blenders credit may go against World Trade Organization rules.

Biofuels as an industry owes itself to federal policy, but the current policies do not meet the goals they were meant to reach and, as such, should not be continued. If left to the market, cellulosic ethanol is unlikely to develop; however, the possible environmental effects of its production could make it undesirable. The future of transportation fuels in the United States will not be fossil fuels, but it will not rely on biofuels either. Future policies should focus on fuels that can replace 100% of fossil fuels and that do not have the same negative externalities of fossil fuels and biofuels.

APPENDIX A: GLOSSARY

Advanced biofuel – biofuel that achieves a 50% reduction in greenhouse gas emissions from 2005 baseline levels

Agricultural residues – see: Crop residues

Air pollutant – chemical, particulate, or biological material in the environment that cause harm to humans and animals

Aquifer – layer of highly permeable rock that contains water, often used as the source of water for wells

Bioenergy feedstock – plant that can be used to make biofuels, including corn, soybeans, sugarcane, switchgrass, and trees

Biofuel – a fuel made from biological sources including bioenergy feedstocks

Biomass-based diesel – diesel fuel made from bioenergy feedstock that achieves a 50% reduction in greenhouse gas emissions from 2005 baseline levels

Blender – a company that mixes biofuels with conventional transportation fuels such as gasoline and diesel

Carbohydrate – organic compound made of Carbon, Hydrogen, and Oxygen, commonly referred to as starch

Cellulose – organic compound made of $C_6H_{10}O_5$, provides the structure of cell walls in plants, source material used in cellulosic ethanol

Cellulosic ethanol – biofuel made from non-food bioenergy feedstock that contains cellulose and that achieves a 60% reduction in greenhouse gas emissions from 2005 baseline levels

Consumer Price Index – measure by the federal government of the change in price of specific common goods and services purchased by household level consumers

Conventional biofuel – biofuel that achieves a 20% reduction in greenhouse gas emissions from 2005 baseline levels

Corn – common grain crop used in the production of ethanol

Corn stover – crop-residue left over from corn production

Crop-residue – plant material discarded after the harvest of crops

Crop rotation – agricultural practice of alternating crops across growing seasons to improve soil sustainability

Dedicated bioenergy crop – crop grown for the purpose of conversion to biofuel, has few other uses and is not used as a food source

Distillation – the process of removing water and other compounds from ethanol by heating to ethanol's boiling point

Dried distillers grains with solubles – solid waste from the production of corn ethanol, used as a livestock feed

Fertilizer – compound applied to soil to increase nutrients for plants

Forest residue – plant material discarded after the harvest of trees

Gasohol – a blend of gasoline and ethanol, current EPA rules limit the blend to 15% ethanol, 85% gasoline; however the most common blend is 10% ethanol, 90% gasoline

Glucose – one kind of carbohydrate, a simple sugar that can be turned into alcohol through fermentation

Glycerol – simple polyol compound made up of three hydroxyl groups, basic compound in making triglyceride

Green diesel – diesel that can be used identically to petroleum diesel but is derived from renewable resources

Greenhouse gas – gas produced naturally and by humans that traps heat in the atmosphere

Hemicellulose – heteropolymer in plant cell walls

Hypoxia zone – zone in a body of water that does not contain enough dissolved oxygen to sustain life, often called a dead zone

Life-cycle analysis – assessment of environmental impact of a product from beginning to end

Lignin – polymer compound in secondary plant cell walls

Liquefaction – process of turning a solid into a liquid by breaking down polymer bonds

Mash – liquid mixture made after enzymes have broken down starches into sugars

Market externality – cost or benefit not incorporated in price caused by market inefficiencies

Meal – flour made from grinding solids after the oils have been removed

Miscanthus — genus of perennial grasses

Municipal solid waste – garbage, common waste from heterogeneous sources

Native forestland – forest that was not planted by humans, natural forest

Native grass – grass that naturally grows in the wild

Perennial crop – crop that lives multiple years even after harvesting and does not require a new seeding every year

Renewable fuel – fuel made from renewable source materials, including biofuels

Renewable Fuel Standard – policy by the U.S. federal government mandating the production and blending of renewable fuels

Transportation fuel – fuel used to power vehicles including gasoline, diesel, and blends, including biofuels

Triglyceride – compound derived from glycerol and three fatty acids

Salinity – Salt content of water or soil

Short-rotation woody crop – fast growing tree that can be used to make biofuels

Soil sustainability – practice of ensuring soil contains enough nutrients to grow plants and using plants to prevent erosion

Soybean – oil seed legume grown in the Midwest, can be used to make biodiesel

Subsidy – payment or economic benefit made to a business or individual from government

Switchgrass – grass native to North America

Syngas – synthetic gas containing carbon monoxide and hydrogen, can be used as a fuel source or transformed into a more efficient fuel

Tariff – tax on imports into a country

Vegetable oil – lipid made from plants

Volumetric Ethanol Excise Tax Credit – policy of the U.S. federal government to provide subsidies to blenders of biofuels and conventional fuels

APPENDIX B: CONVERSIONS

1 square mile = 640 acres

1 hectare = 2.47 acres

1 acre = 43,560 square feet

1 barrel = 42 gallons

1 bushel = 8 dry gallons

1 bushel = 2,150.42 cubic inches

1 ton = 2,000 pounds

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