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THE ENERGY INDEPENDENCE AND SECURITY ACT OF 2007: CAN BIOTECHNOLOGY HELP OVERCOME POTENTIAL OBSTACLES TO MEETING ITS ENERGY GOALS?

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I. INTRODUCTION

Concerns with fossil fuel use, the environment, and the security implications of the United States' dependence on foreign oil have led our government to implement a variety of policies and regulations through the years. As these concerns appear to be ongoing, Congress passed the Energy Independence and Security Act of 2007 ("EISA" or "Act")¹ in an effort to set new energy goals and fund additional research into new methods for addressing the concerns.² Although EISA includes a variety of mandates, its biofuel production goals, and the research being done to determine the best way to meet those goals, are the central focus of this Article. In addition to setting a cap on the production of corn ethanol, these biofuel goals call for a large amount of cellulosic biofuel to be in production by 2022.³ This goal may be overly optimistic considering no cellulosic biofuel is currently being produced on a commercial level in the United States.⁴

As with any policy change, there are both benefits and obstacles to EISA’s biofuel production goals. Aside from the obvious advantages of decreasing oil imports and supplementing oil reserves, benefits include a reduction of adverse environmental impacts, such as decreased greenhouse gas ("GHG") emissions, when compared with petroleum-based fuels.⁵ Cellulosic crops dedicated to biofuel production would also potentially decrease soil erosion, increase nutrients in the soil, and decrease the use of fertilizers, pesticides, and herbicides.⁶

A variety of obstacles to EISA’s goals exist. One obstacle is the lack of an adequate infrastructure for processing cellulosic biomass and for

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³ Id. at 1, 5.
⁵ Infra Part III.A.
⁶ Id.
distributing the resulting ethanol. Also, automobiles capable of using fuel with higher ratios of ethanol to gasoline must be designed and manufactured. The most significant obstacles, though, are the biological barriers encountered with the use of cellulosic biomass. These barriers include the recalcitrance of cellulosic biomass, the difficulty converting into ethanol the 5- and 6-carbon sugars resulting from the hydrolysis of hemicellulose, and the fact that lignin, which cannot be broken down for conversion into ethanol, makes up 25% of the plant cell wall. Biotechnology methods look promising for addressing these biological barriers. Many studies are already underway utilizing methods like gene modification and gene engineering to decrease the recalcitrance of cellulosic biomass, improve the fermentation process for a higher ethanol yield, and alter cellulosic crops.

To thoroughly analyze this information, this Article is divided into five parts. In Part I, some of the history behind EISA’s implementation is discussed, and its mandated goals for biofuel production and use are described. Part II includes information about biofuels, first through a general description of biofuels and the two main types of feedstock used for its production, and then through a detailed discussion of cellulosic feedstock specifically. The benefits of and obstacles to EISA’s mandated biofuel production goals are addressed in Part III, while Part IV outlines the biotechnology research currently being performed in an attempt to resolve the biological obstacles to EISA’s cellulosic biofuel goals. Part V provides an analysis of EISA and its goals.

II. THE ENERGY INDEPENDENCE AND SECURITY ACT OF 2007

The Energy Independence and Security Act of 2007 is the result of growing national concerns that include not only the obvious concerns of rising oil prices and decreasing oil reserves, but also many less obvious, yet equally significant, concerns. Pollution from the use of fossil fuels and its subsequent effects on the environment have generated an interest in finding sustainable energy sources that will decrease air pollution and GHG emissions, thus decreasing the effects of fossil fuels on global climate change. Also, there is a growing national security concern with the United States’ ever increasing dependence on foreign oil. To help address these concerns, Congress passed EISA, which mandates changes in alternative fuel use and research.

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7 See infra Part III.B.3.  
8 See infra Part III.B.2.  
9 See infra Part III.B.1.  
10 Biofuels, infra note 55; Plant Cell Walls, infra note 64; Fuel Ethanol, infra note 41.  
11 See infra Part IV.  
A. History Leading to the Current Act

Some of the first policies encouraging ethanol production were adopted during World War II. The emergency created by the wartime disruption of imported fuel supplies led to the concept of using ethanol to help develop domestic fuel reserves. After the war, domestic oil reserves began shrinking rapidly as petroleum-based fuel use increased with the growth of the country’s population. With many parts of the world growing at the same rapid pace as the United States, oil demand outpaced the oil supply, and oil shortages were apparent.

By the 1970s, the United States was transformed from a major oil producer to a country dependent on foreign oil. This transformation, along with a variety of fossil fuel-related events that occurred in the 1970s, led to the reemergence of ethanol as a possible motor fuel. The first of these events was the growing concern with the use of lead additives in gasoline. The lead in automobile exhaust was determined to cause damage to the central nervous system and to increase blood pressure in those who inhaled or ingested it. Consequently, the Environmental Protection Agency (“EPA”) began phasing out leaded gasoline in the 1970s, with the complete “elimination of lead from all U.S. motor fuel by January 1, 1996” mandated by the Clean Air Act Amendments of 1990 (“CAA”). Because lead initially was added to gasoline to boost its octane rating and prevent “knocking,” ethanol was suggested as a replacement additive, as it provides the same results.

Later, the serious air pollution resulting from petroleum-based fuel became a major environmental factor driving additional government fuel policies. The CAA established both the Oxygenated Fuels Program and the Reformulated Gasoline Program (“RFG”) in an attempt to address urban air pollution from various car emissions, such as carbon monoxide. Carbon monoxide is a greater problem in urban areas experiencing heavy

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14 Id.
15 Id.
16 Id.
17 Id.
18 Id. at 425, 427.
20 Id.
22 Duffield, Xiarchos & Halbrook, supra note 13, at 430–31.
23 Id. at 431.
traffic during the winter months, as the carbon monoxide becomes trapped near the ground by temperature inversions.\textsuperscript{24} Consequently, both programs required gasoline in these areas to contain two percent oxygen during the winter months, resulting in more complete fuel combustion and decreasing carbon monoxide and other dangerous emissions.\textsuperscript{25} Ethanol was one of the products used as an oxygenate.\textsuperscript{26}

A third fossil fuel-related event in the 1970s involved the Organization of Petroleum Exporting Countries ("OPEC").\textsuperscript{27} Taking advantage of the growing shortage in oil supplies, OPEC raised prices to the point that crude oil market prices doubled between 1970 and 1973.\textsuperscript{28} On the heels of the oil shortage, with increasing political tension and military events in the Middle East, Arab oil ministers eventually cut their oil production and embargoed the United States in 1973.\textsuperscript{29} The Arab oil embargo led not only to gasoline shortages, but also to the change in power over foreign oil to OPEC.\textsuperscript{30} As various issues impacting oil supplies continued to arise in the Middle East, the United States began contemplating other strategies for responding to increased fuel needs. Utilizing agriculture as a source of energy in the form of ethanol and other renewable energy sources emerged as a viable strategy.\textsuperscript{31}

A variety of government environmental and energy policies and government regulations have been implemented in the years since these events.\textsuperscript{32} These policies include those supporting a United States ethanol industry.\textsuperscript{33} This involvement by the government has contributed significantly to the growth of the ethanol industry. Continued involvement, such as the implementation of the Energy Independence and Security Act of 2007, will be important to the future of the ethanol industry.\textsuperscript{34}

\textsuperscript{24} Id. at 447.
\textsuperscript{25} Id. at 431, 447.
\textsuperscript{26} Id. at 431. The two percent oxygenate requirement was later eliminated by the Energy Policy Act of 2005. Id. at 448.
\textsuperscript{27} Id. at 427.
\textsuperscript{28} Id.
\textsuperscript{29} Id.
\textsuperscript{30} Id. at 427–28.
\textsuperscript{31} Id. at 428.
\textsuperscript{32} Id. at 438.
\textsuperscript{33} Id. at 425.
\textsuperscript{34} Id. at 425.

The past thirty years have brought a variety of legislation concerning energy policy for the United States. Recently, there has been increased congressional interest in petroleum alternatives, such as the biofuels corn ethanol and biodiesel. As a result of this interest, Congress enacted EISA. This Act, also referred to as the 2007 Energy Bill, is "an omnibus energy policy law" meant to increase energy efficiency and establish a standard for renewable energy.

As EISA is an expansion of The Energy Policy Act of 2005 ("EPAct"), it is necessary to understand the basics of the EPAct before discussing EISA’s key provisions. EPAct was passed in 2005 and mandated phasing in renewable fuels by utilizing a renewable fuel standard ("RFS"). The EPAct RFS required increasing amounts of renewable fuels to be used in gasoline, starting at four billion gallons in 2006 and increasing to 7.5 billion gallons in 2012. After 2012, EPAct required the renewable fuel-to-gasoline ratio to meet or exceed the 2012 ratio. Another important provision of EPAct was the creation of the Cellulosic Biomass Program to encourage the production of ethanol from cellulosic biomass, such as corn stover or switchgrass. EPAct required a minimum of 250 million gallons of biofuel from cellulosic biomass to be included in the mandated amounts of renewable fuel used in gasoline beginning in 2013.

EISA, signed into law on December 19, 2007 and implemented January 1, 2008, includes several key provisions addressing a variety of energy technologies. The most important provision for the purposes of this Article is the significant expansion of the RFS requirements from those in EPAct. EISA raises the requirement for annual biofuel production by 2022 from 8.6 billion gallons under the EPAct to thirty-six billion gallons. Of those thirty-six billion gallons, EISA caps ethanol from corn or other
grains at fifteen billion gallons and requires no less than twenty-one billion gallons to be “advanced” biofuel. Advanced biofuels are those produced from any non-cornstarch feedstock “with fifty percent lower lifecycle GHG emissions.” Examples of advanced biofuels include cellulosic biofuels and biomass-derived diesel substitutes.

Due to concerns that biofuels may affect corn or grain prices, or that there may be negative environmental effects from this push for biofuels, EISA requires the Department of Energy (“DOE”), in consultation with the United States Department of Agriculture (“USDA”) and the EPA, to “enter into an agreement” with the National Academy of Sciences (“NAS”) to perform impact studies. No completion date for these studies has been set, but the NAS must assess the effects of the RFS on any industries associated with feed grains, livestock, food, forestry, and energy and propose the most effective ways to limit potential adverse economic impacts. The EPA, working with the DOE and the USDA, also must perform impact studies on environmental issues, resource conservation issues, and invasive species of cellulosic crops.

Other important provisions of the legislation include support for research and development, improved infrastructure, advancement of cellulosic biofuels production technology, and the conversion of corn ethanol biorefineries to refineries that would produce cellulosic ethanol. Environmental concerns have led to additional GHG emission requirements as well: (1) new ethanol biorefineries producing renewable fuels must have at least 20% lower GHG emissions than petroleum fuels, and (2) the DOE is required to establish a grant program for any advanced biofuels produced that have at least an 80% reduction in GHG emissions as compared to fuels currently in use.

To summarize, concerns with oil prices, the environment, and the security implications of the United States’ dependence on foreign oil have led to a variety of government policies and regulations, including EISA. Although EISA includes a variety of energy mandates, the biofuel production requirements mandated by EISA are the central focus of this Article. The anticipated positive outcomes of these requirements are accompanied by potential obstacles as well. With no cellulosic biofuel currently being produced commercially in this country, the mandated

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45 Duffield, Xiarchos & Halbrook, supra note 13, at 439.
46 Capehart, Schnepf & Yacobucci, supra note 2, at 5.
47 Id.
48 Id.
49 Id.
50 Id.
51 Id. at 6.
52 Duffield, Xiarchos & Halbrook, supra note 13, at 440.
53 Capehart, Schnepf & Yacobucci, supra note 2, at 5–6.
production of thirty-six billion gallons of biofuel by 2022, with no less than twenty-one billion gallons of that total from “advanced” biofuels, may be too optimistic. To better understand the challenges this new RFS creates for the biofuel industry, particularly with cellulosic biofuels, it is necessary to have a better understanding of biofuels in general and of the different types of biomass that can be used to create cellulosic biofuel.

III. BIOFUELS

The concept of biofuels has been around for many years. Remarkably, Henry Ford stated in 1925:

The fuel of the future . . . is going to come from fruit like that sumach out by the road, or from apples, weeds, sawdust—almost anything. There is fuel in every bit of vegetable matter that can be fermented. There’s enough alcohol in one year’s yield of an acre of potatoes to drive the machinery necessary to cultivate the field for a hundred years.54

Ford’s prediction is being fulfilled today.

A. General Background

Ford’s “fuel of the future,” called biofuel today, is a liquid, solid, or gaseous fuel made from biologic material.55 The biologic material used to create biofuels is called biomass or feedstock, and while it usually consists of plant matter or its derivatives, it may also consist of other organic matter, such as animal waste, municipal solid waste, bacteria, and algae.56 Biomass encompasses both the edible and inedible portions of plant matter.57 Examples of edible biomass are “sugars from sugar cane or sugar beets, starches from corn kernels and other grains, and vegetable oils.”58 Inedible biomass includes the following: the woody or fibrous portions of plants, such as corn leaves and stalks or wheat straw; tree limbs or other excess forest vegetation; wood chips and sawdust; and special crops grown specifically for biofuel production.59
All inedible biomass contains the structural components of plant cell walls, which are cellulose, hemicellulose, and lignin. Due to the presence of these components, inedible biomass generally is called either "cellulosic" or "lignocellulosic" biomass. The cellulose and hemicellulose portions of the cellulosic biomass are polysaccharides that can be broken down to simple sugars and then fermented to produce ethanol. The lignin portion, however, which makes up about 25% of cellulosic biomass, is a complex noncarbohydrate polymer that makes plant cell walls rigid. Because this component cannot be broken down into simple sugars for conversion to ethanol, the efficiency of converting cellulosic biomass to ethanol is decreased. The best use of the lignin portion must be determined before the yield of energy from cellulosic biomass can be maximized.

B. Inedible or Cellulosic Biomass

Ethanol produced from edible biomass like corn makes up much of the biofuel currently used in the United States, with biodiesel making up the remainder. The EISA biofuel requirements, though, will push cellulosic biofuel to the forefront by 2022. This is largely because cellulosic biomass is such a promising biofuel feedstock. It is a renewable source, domestic, and the most plentiful biologic material on earth due to the variety of biomass that potentially can be used as cellulosic biofuel feedstock.

Certain types of cellulosic feedstock are already available for use, such as wood chips, sawdust, and crop residue like rice and wheat straw or corn stover. Forest woody biomass is also available and consists of logging residue, biomass from forest management and clearing, fuel wood, and

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60 Id.
61 Id.
63 Biofuels, supra note 55.
65 BARRIERS, supra note 62, at 53.
67 See CAPEHART, SCHNEPP & YACOBUCCI, supra note 2, at 5.
68 BARRIERS, supra note 62, at iii.
perennial woody crops. Other types of cellulosic feedstock would come from crops specifically planted for use as cellulosic biofuel. These crops include perennial grasses, such as *Miscanthus*, switchgrass, reed canary grass, prairie cordgrass, *Brachypodium distachyon*, and tropical grasses. A variety of trees also may be used, such as "poplar, hybrid poplar, willow, silver maple, black locust, sycamore, sweetgum, and eucalyptus."

In summary, although corn ethanol makes up a large portion of biofuel in use today, EISA mandates a cap on corn and grain ethanol and an increase in cellulosic ethanol by 2022. The abundance of available cellulosic biomass supports this direction, but the difficulty, complexity, and cost of converting cellulosic biomass into ethanol raises questions about the attainability of EISA’s goals.

IV. IMPLEMENTING THE ENERGY INDEPENDENCE AND SECURITY ACT: ANTICIPATED BENEFITS AND POTENTIAL OBSTACLES

In his 2006 State of the Union address, President George W. Bush declared that “America is addicted to oil.” He then set a goal to replace 75% of United States’ oil imports from the Mideast with ethanol and other sources by 2025. EISA is one of many steps Congress has taken to address growing concerns with energy and the United States’ dependence on oil. But, as with any new program, there are both anticipated benefits and potential obstacles with the biofuel mandates in the legislation.

A. Anticipated Benefits

There is no doubt there are many benefits from using cellulosic biofuel besides the obvious one of decreasing the United States’ dependence on foreign oil. Some of the benefits have been determined through research using cellulosic biomass, such as the decrease in GHG emissions, the decrease in fertilizer use, and the increase in ethanol production as compared with edible biomass. Others are anticipated benefits and include positive environmental impacts and the ability of cellulosic biomass to grow on marginal land.

1. Benefits of Cellulosic Biomass over Edible Biomass

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70 CAPEHART, supra note 66, at 4.
71 Biofeedstocks, supra note 69.
72 Id.
73 CAPEHART, SCHNEPF & YACOBUCI, supra note 2, at 5.
75 Id.
Cellulosic biomass has several benefits over edible biomass besides its abundance and diversity. One important benefit is that biofuel-specific cellulosic crops can be grown on marginal land that is not suited for food crops, thus reducing the competition between food and fuel crops.\textsuperscript{76} The types of land on which these crops can be grown could be further expanded by genetically modifying the crops to tolerate drought, freezing, soil with high salinity, or other environmental stressors.\textsuperscript{77} Additional benefits include various improved outcomes exhibited by cellulosic feedstock over edible feedstock when converted into ethanol. These variable outcomes should be taken into account when determining which type of crop would be best utilized in various parts of the country and on different types of land.

The first benefit of cellulosic biomass over edible biomass is in the amount of ethanol produced per acre. \textit{Miscanthus}, which grows well on marginal lands, produces one of the largest volumes of ethanol.\textsuperscript{78} Research performed in Illinois demonstrated a production volume of 1,100 gallons of ethanol per acre, which is about 2.5 times the approximately 425 gallons an acre produced from corn.\textsuperscript{79} Switchgrass, which does not reach its full yield potential until its third year of production, can produce between 550 to 1,000 gallons of ethanol per acre.\textsuperscript{80} Another fairly high producer of ethanol is woody biomass, such as hybrid poplar, willow, or eucalyptus trees, generally grown on tree plantations.\textsuperscript{81} Although these trees are slow to mature, one acre can produce approximately 700 gallons of ethanol.\textsuperscript{82} One of the lowest ethanol yields comes from crop residue like wheat straw or corn stover, with early research demonstrating a yield of only 180 gallons of ethanol per acre.\textsuperscript{83}

Improved reduction in GHG emissions is a second benefit of cellulosic biomass over edible biomass. While corn ethanol only reduces emissions by 31\% compared to gasoline, \textit{Miscanthus} reduces GHG emissions by 89\%.\textsuperscript{84} Corn stover provides the next largest reduction with 86\%, followed by switchgrass with a 53\% reduction in GHG emissions.\textsuperscript{85}

\textsuperscript{77} id.
\textsuperscript{78} CAPEHART, supra note 66, at 5–6.
\textsuperscript{79} id. at 6.
\textsuperscript{80} id. at 5.
\textsuperscript{81} id. at 6.
\textsuperscript{82} id.
\textsuperscript{83} id. at 5.
\textsuperscript{85} id.
This large GHG emission decrease with cellulosic feedstock is partly due to the fact the lignin in the feedstock is "a renewable fuel with no net [GHG] emissions." Lignin can be used to fuel the conversion of cellulosic biomass into ethanol, while corn ethanol uses fossil fuels in its conversion process. Fossil fuels create significant GHG emissions that affect the overall calculations for GHG production.

The use of two different conversion fuels, lignin versus fossil fuels, also produces a difference in the net energy balance (NEB) of corn ethanol and cellulosic ethanol. NEB compares the ratio of per-unit energy produced by a biofuel with the energy in the fossil fuel used in a fuel's production. Because of the fossil fuels used in corn ethanol production, corn ethanol's NEB was estimated to be 67% in 2004, a number some considered overly optimistic. An NEB of this level means there is 67% more energy in the corn ethanol than in the fossil fuel used in its production. Although NEB varies based on the production and processing methods used, cellulosic biomass NEB estimates range from 300% to 900%, significantly better than corn ethanol.

An additional benefit results from the fact that most crops with the potential to provide cellulosic biofuel are perennial crops, rather than annuals like most edible feedstock. Perennials maintain considerable tissue mass below ground during their dormant season, which allows the above-ground portion to develop very quickly in the spring. Faster above ground growth yields a higher carbon fixation rate of photosynthetic carbon dioxide ("CO₂"), which increases the annual amount of biomass per acre. Consequently, perennials are already increasing their biomass while annual plants are only seedlings.

A final benefit is that cellulosic biomass provides a feasible solution to much of the "food versus fuel debate" concerning the use of corn crops. Although the United States farm sector has benefited economically from the use of corn as a biofuel, experiencing three of the highest years for farm income in the past four years, others are not as happy
The debate surrounding the use of corn for fuel centers around three basic arguments. First, some argue that growing biofuel crops wastes quality, fertile cropland that is otherwise suitable for growing food crops. Cellulosic feedstock, however, grows well on both marginal and surplus agricultural land; thus, it does not compete for land needed for growing food crops. Second, there is a concern that the diversion of corn away from its use for food has contributed to a rise in food costs. While the impact of higher prices may not significantly affect most United States’ consumers, low-income consumers in foreign countries that rely on United States’ corn exports have faced significantly increased food prices, particularly in those countries where corn products are a staple of their regular diet. Finally, there are concerns with the increase in cost for animal feed, as historically, one of the major uses of corn is for animal feed. In 2000, a year in which the average price for corn was $1.85 per bushel, over 50% of the corn crop was used in animal feed. Corn used for ethanol, though, jumped from 10% in 2002 to an estimated 24% in 2007, with the price of corn also increasing to $3.76 per bushel at the end of that year. This increase in the cost of corn significantly impacts the cost of raising livestock, generating fear that meat production may slow and the cost of meat may rise. As cellulosic biofuel approaches the goal set by EISA, prices of corn will likely drop to a level that, while still economically beneficial to farmers, is more affordable for use as food and animal feed.

2. Environmental Benefits

A number of positive environmental outcomes are anticipated with cellulosic biofuel crops in addition to reducing GHG emissions. For example, cellulosic crops need less petroleum-based fertilizer than corn. Fertilizer-rich runoff water can pollute groundwater, which has led to “dead zones”—areas of very low oxygen in water—such as those found in the Gulf of Mexico. The large difference in fertilizer use between corn and cellulosic biofuel crops is likely because cellulosic crops are perennials, which store minerals in their root systems for the following year, decreasing

98 Id. at 444.
99 Biomass Research, supra note 76.
100 Duffield, Xiarchos & Halbrook, supra note 13, at 444.
101 Id. at 444-45.
102 Id. at 442-43.
103 Id. at 442.
104 Id. at 442-43.
105 Id. at 444.
106 AAAS CTR. FOR SCI., TECH. & CONG., AAAS POLICY BRIEF: BIOFUELS, http://www.aaas.org/spp/cstc/briefs/biofuels/ (last visited Jan. 22, 2011) [hereinafter AAAS BIOFUELS]; see CAPEHART, supra note 66, at 14 (explaining that switchgrass, one type of cellulosic biofuel crop, uses far less fertilizer than corn).
107 AAAS BIOFUELS, supra note 106.
the amount of fertilizer that must later be applied. The same is not true for an annual crop like corn. Additionally, cellulosic biomass reduces insecticide use, as it has fewer natural insect predators.

Cellulosic biofuel-specific crops, such as perennial grasses, decrease soil erosion and the loss of soil nutrients. The environmental and soil conservation practice of no-till cultivation lends itself well to these crops, which leads to exceedingly low rates of erosion. Because these crops have such extensive root systems, nutrient capture rates are high, while the loss of nutrients to water is low. The capture of nutrients allows soil fertility to increase over time.

To maintain these benefits of decreased soil erosion and increased soil fertility, the land on which the cellulosic biofuel crops are grown must be utilized appropriately. For example, corn stover and rice or wheat straw are good candidates for cellulosic biofuel, but if too much stover or straw is removed from the land, an increase in soil erosion and decreased soil fertility may result. Studies have indicated that up to 60% of stover or straw residue can be removed without undue effects to soil nutrition or erosion. These decreases in tilling, fertilizer use, and pesticide use decrease the cost of raising cellulosic feedstock over edible feedstock by a factor of roughly two on a per ton basis.

In summary, the anticipated benefits of cellulosic biofuels are numerous. Greatly decreased levels of GHG emissions, coupled with greatly increased volumes of ethanol produced per acre, look promising in terms of meeting the “advanced” fuel goals set by EISA. Aiding the environment through the decreased use of fertilizers, insecticides, and pesticides, as well as decreasing soil erosion, are additional benefits to the use of cellulosic biomass. Even with these very promising outcomes, however, there are potential obstacles to consider as cellulosic biofuel is studied for wide-spread future use.

108 See Biofeedstocks, supra note 69.
109 See id.
110 Id.
111 Id.
114 Id.
115 CAPEHART, supra note 66, at 5.
116 Id.
117 LYND, supra note 113, at 1.
B. Potential Obstacles

In spite of the many anticipated benefits, potential obstacles must be considered as the United States gears up to meet EISA’s cellulosic fuel mandates. Some of these obstacles include the invasiveness of some cellulosic feedstock crops when planted in a non-native environment and the special storage space and machinery that may be necessary due to the natural bulkiness of cellulosic biomass. Additional concerns are the lack of infrastructure for producing and transporting cellulosic biofuel and the need to develop and produce automobiles that can run on higher percentage blends of ethanol with gasoline.

While these obstacles are not insignificant, the focus of this Article will be on the biological barriers to cellulosic ethanol production. Many of these biological barriers, such as the complexity of cellulosic biomass, the difficulty breaking this biomass down into the simple sugars needed for fermentation, and the presence of lignin, can be addressed through biotechnology. Critics of cellulosic biofuel, however, argue that any benefits from using this feedstock will be outweighed by the costs, as these barriers make converting cellulosic biomass into ethanol more expensive and less productive than the conversion of corn grain to ethanol.

I. Biological Barriers

Several biological barriers exist in converting cellulosic biomass into ethanol that are nonexistent when converting edible biomass into fermentable sugars. The most significant barrier is the recalcitrance of cellulosic biomass, which refers to the difficulty encountered when attempting to break down complex cellulosic biomass into fuel. Due to this difficulty, several processing steps are required for cellulosic feedstock conversion, leading to higher costs.

First, harsh pretreatment methods are necessary to separate the cellulose and hemicellulose from the rigid lignin in the plant cell wall. Three different pretreatment methods are currently used in pilot or demonstration biorefineries: (1) dilute or concentrated acid hydrolysis; (2) enzymatic hydrolysis following a pretreatment process; and (3)
Both acid hydrolysis methods use sulphuric acid. The dilute method involves high temperatures and pressure and results in low sugar recovery, while the concentrated method increases sugar recovery but requires longer processing times and the necessary recovery of large amounts of acid. Enzymatic hydrolysis uses cellulase enzymes, the cost of which is the most significant barrier with this type of pretreatment. If the thermochemical pretreatment process is used, the chemical byproducts of the process may inhibit the enzyme hydrolysis processing step and may also decrease the effectiveness of the fermentative microbes.

Following the pretreatment step, the “hemicellulose is hydrolyzed into a soluble mix of 5- and 6-carbon sugars,” and the liquefied hemicellulose sugars are then separated from the solid fibers that contain crystalline cellulose and lignin. This mix of 5- and 6-carbon sugars is the second biological barrier in the production of ethanol from cellulosic biomass. Although microorganisms do exist that can ferment this mix of sugars, their ethanol production rate is lower, with the broth produced by fermentation containing only about 6% ethanol rather than the 10% to 14% seen with cornstarch glucose fermentation. In addition, the organisms which are capable of fermenting this sugar mix have a lower tolerance for the ethanol that is produced and, thus, do not do well in this environment.

Further processing steps must address the biological barriers of the crystalline structure of cellulose and the remaining lignin residue. The crystalline structure of cellulose requires further treatment with cellulase enzymes to separate the cellulose from the crystal and to further break down the cellulose into glucose. Ethanol is then produced when yeast or other microorganisms consume the glucose during fermentation. As lignin cannot currently be broken down, and may even interfere with enzymatic polysaccharide conversion, it is removed from the ethanol and put to some other use. As mentioned previously, it may be used to provide the energy necessary to convert cellulosic biomass into ethanol. Lignin, which has an “energy content similar to coal,” can produce enough energy to power the conversion of biomass into ethanol and still have...
enough residue left to be used as an electricity source.\textsuperscript{139} Process design studies have demonstrated that the several steps required to overcome the recalcitrance of cellulosic biomass are "the most costly, involve the greatest technical risk, and have the largest potential" for being reduced through further research.\textsuperscript{140}

2. Lack of Infrastructure

Even if cellulosic biofuel could be produced today, a significant amount of infrastructure necessary to convert and transport cellulosic biofuel is lacking. One of the first infrastructure needs is the creation of biofuel plants—biorefineries—for converting cellulosic biomass into ethanol on a commercial scale. Currently, only a few small demonstration biorefineries are converting cellulosic biomass into ethanol.\textsuperscript{141} This is largely due to the unique characteristics of cellulosic biomass that make building a commercial-scale biorefinery nearly cost prohibitive.\textsuperscript{142} Because of the large variety of cellulosic feedstocks available, these refineries must house the processing technologies necessary for every type of feedstock.\textsuperscript{143} Moreover, cellulosic biomass is much bulkier than most edible biomass, necessitating larger storage facilities and processing areas at the biorefineries.\textsuperscript{144}

These characteristics suggest that cellulosic biorefineries need to be much larger than most corn ethanol plants,\textsuperscript{145} making their cost much higher. To be economically viable, it is estimated that cellulosic biorefineries will need to process 5,000 to 10,000 tons of biomass daily.\textsuperscript{146} Brent Erikson, Vice President of the Biotechnology Industry Organization, states that "[c]apital is a problem," with the construction of a commercial

\textsuperscript{139} Two processes used to produce power from lignin are direct combustion with the generation of steam power and gasification. Gasification involves burning the lignin in a closed process under elevated air pressure with some oxygen. This results in raw fuel gas and ash that can be later used on fields of feedstock crops. \textit{id.}

\textsuperscript{140} \textit{LYND, supra note 113, at 3.}

\textsuperscript{141} POET, America’s largest ethanol producer, has an eight million dollar test facility located in South Dakota, where 20,000 gallons of cellulosic ethanol are made each year from corn cobs. Mark Clayton, \textit{The 'Holy Grail' of Biofuels Now in Sight, THE CHRISTIAN SCI. MONITOR}, Feb. 13, 2009, available at \texttt{http://www.csmonitor.com/Innovation/Energy/2009/0213/the-holy-grail-of-biofuels-now-in-sight}. The logen Company has a small biorefinery in Ottawa, Canada that annually produces about 260,000 gallons of ethanol from cellulosic biomass using enzyme hydrolysis followed by fermentation, while a Japanese company utilizing acid hydrolysis to process waste is also producing ethanol in Izumi, Japan. Greer, \textit{supra note 86.}

\textsuperscript{142} See Greer, \textit{supra note 86.}

\textsuperscript{143} \textit{id.}

\textsuperscript{144} \textit{id.}


\textsuperscript{146} Greer, \textit{supra note 86.}
size biorefinery estimated to cost between $200 and $250 million. The U.S. government is committed to helping offset some of this expense. For example, the DOE is paying 40% of the $200 million cost of a 25 million gallon commercial-scale biorefinery to be constructed in Emmetsburg, Iowa, which is expected to open in 2011. An alternative to constructing new cellulosic biorefineries is to convert some existing corn-based ethanol refineries into refineries with the capacity to process cellulosic materials. This may not be practical, though, as corn ethanol refineries would need to be significantly enlarged, which is costly.

The bulkiness of cellulosic biomass also impacts transportation. Decentralized biorefineries must be located closer to feedstock sources due to the difficulty in transporting cellulosic feedstock. Moving the biorefineries closer to the sources and further from retail outlets, however, creates an additional obstacle. As with corn ethanol, current pipelines for transporting gasoline cannot be utilized for moving cellulosic ethanol from these decentralized refineries because the ethanol absorbs the water often present in these pipelines, ruining the ethanol, and the ethanol will erode the pipes. As a result, instead of being blended with gasoline at the refinery, ethanol must be transported to mixing sites closer to retail outlets, where it can be blended in immediately prior to delivery. Although these transportation and blending issues are not unique to cellulosic ethanol, the large increase in biofuel production mandated by EISA will require the transportation of much larger quantities of ethanol, possibly overburdening the truck, rail, and barge industries. The cost of improving the transportation infrastructure to accommodate these needs will add expense to the overall cellulosic fuel process.

3. Necessary Vehicle Upgrades

To meet the high volume of cellulosic biofuel use mandated by EISA, an increase in the percentage of ethanol blended with gasoline for use in all vehicles will likely be necessary. The EPA recently waived its

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147 The Iogen Company plans to build a commercial-scale facility in western Canada, the United States, or Germany and estimates the cost will be $350 million. Id.
148 Clayton, supra note 141.
149 See CAPEHART, SCHNEPF & YACOBUCI, supra note 2, at 8 (identifying the conversion of corn ethanol refineries into cellulosic biorefineries as a research goal of the Energy Independence and Security Act).
150 Halff, supra note 145, at 412 (explaining that “feedstock supply capacity constraints are . . . putting an unexpected crimp on ethanol production growth both physically and financially”).
151 Id.; Greer, supra note 86.
152 AAAS BIOFUELS, supra note 106.
153 Id.; Biofuels, supra note 55.
154 See AAAS BIOFUELS, supra note 106.
155 Id. (explaining that DOE announced in 2009 that “it would award $30 million in biofuel infrastructure grants to 17 companies”).
limitation restricting ethanol-gasoline blends to 10% and now allows 15% blends to be commercially available for vehicle models 2007 or newer. There are problems with that move, however. Currently, in the United States, all new car warranties cover the use of 10% ethanol-90% gasoline blends. Increasing this ratio could have not only some impact on vehicle performance, but also void existing car warranties. The DOE is currently funding research to evaluate the effect of different blend percentages on existing automobiles, but the EPA must approve the use of higher blend ratios in automobiles before any changes can be made.

A small number of “fuel-flexible vehicles” (“FFV”) that can run on higher ethanol-gasoline blends are already available and in use in some areas of the country. These vehicles can use E85, an 85% ethanol-15% gasoline blend, but they require modifications to make them “alcohol-tolerant.” Modifications required for higher ethanol blends include stainless steel fuel tanks and Teflon-lined fuel hoses that will not be eroded by higher ethanol concentrations. An additional automobile modification required for very high ethanol blends is a larger fuel tank. Because the energy content of ethanol is only about 70% that of gasoline per unit volume, 1.4 gallons of ethanol would be required for every one gallon of gasoline currently used.

In summary, the implementation of EISA, with its cellulosic biofuel mandates, has many anticipated benefits in addition to decreased GHG emissions, including decreased soil erosion, decreased pesticide and fertilizer use, and increased soil fertility. Current research has shown that cellulosic biofuel yields higher volumes of ethanol than edible feedstock, plus cellulosic biofuel may lessen the “food vs. fuel” debate occurring with corn biofuels. The push toward meeting the cellulosic biofuel mandates, however, has also uncovered a variety of potential obstacles. Although infrastructure and modified vehicles are concerns with future EISA goals, the major obstacles to the implementation are biological barriers, such as recalcitrance and inefficient conversion of cellulosic biomass to ethanol.

156 Id.
157 Id.
158 Id. (stating that the EPA has recently sought public comment on such a proposition).
159 See CAPEHART, supra note 66, at 12–13.
160 See AAAS BIOFUELS, supra note 106. Beginning in 2012, the country of Columbia will require all vehicles made and sold in that country to have the ability to operate on E85. This will likely impact United States automobile manufacturers and possibly contribute to moving the American car industry forward in the increased production of FFVs. Mike Ceaser, Colombia Orders Automakers to Transition to Producing Cars Using 85 Percent Ethanol, BioTech Watch, Apr. 29, 2009, available at http://news.bna.com/bwdf/BWDMWB/split_display.adp?fedfid=12019098&vname=btbbulallissues&f n=12019098&jd=A0B8Q0T1K2&split=0.
161 See AAAS BIOFUELS, supra note 106.
162 LYND, supra note 113, at 2.
163 Biofuels, supra note 55.
Various biotechnology methods may provide solutions to these barriers, with research already underway in many areas.

V. USING BIOTECHNOLOGY TO OVERCOME CELLULOSIC BIOFUEL OBSTACLES

EISA acknowledged many of the potential obstacles outlined in the previous section by providing funding for directed research into such obstacles. Because biological barriers provide some of the biggest challenges currently facing cellulosic biofuels, EISA provides for and encourages research and development of new technologies,164 many of which utilize biotechnology. A variety of biotechnology research is currently being performed in an effort to increase cellulosic ethanol production and improve the efficiency of biomass conversion into ethanol.

A. Reducing Recalcitrance

One of the biggest obstacles facing those doing research on cellulosic biofuels is the recalcitrance of cellulosic biomass. To design a low recalcitrance biomass, it is necessary to understand not only the basic relationship between plant cellulose, hemicellulose, and lignin, but also how these integrate into the cell wall.165 Some of the first studies are investigating cell wall structure and synthesis in an effort to understand what genetic modifications can be made to break down these barriers.

One study concentrated on plants containing “tension wood,” a wood tissue that naturally contains increased amounts of cellulose and reduced amounts of lignin.166 Because these are the properties that would result in more efficient ethanol production, this study sequenced the genome of *Populus trichocarpa* in an effort to allow a “genome-wide approach” to obtaining knowledge about the wood’s biosynthesis of cellulose, hemicellulose, and lignin.167 As researchers identify genes that could be associated with these more desirable traits, genetic modification of other dedicated biofuel crops can potentially increase their cellulose content

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164 Duffield, Xiarchos & Halbrook, supra note 13, at 440.
167 Id.
while decreasing the lignin content. Increasing the amount of cellulose in cell walls would provide additional material to break down into glucose, while a decreased amount of lignin would improve access to the cellulose for the enzymes used in the conversion process, increasing glucose amounts for fermentation into alcohol.

The high cost and inefficiency of current enzyme systems at breaking down cellulose and hemicellulose into sugar have led to a variety of studies being performed on the enzyme systems that deconstruct plant cell walls. Some studies are working toward genetically engineering new enzymes for more efficient biomass conversion, while others are searching nature for new enzymes that could more efficiently deconstruct cellulosic biomass or serve as models for future protein engineering of enzymes. One current study is utilizing protein engineering to enhance the thermostability of industrial enzymes used in the enzymatic hydrolysis step of cellulosic biomass conversion. The engineering of these enzymes will "allow for higher specific activity, reduce the amount of enzyme loading during hydrolysis, and allow greater flexibility in process configurations."

Another proposal suggests surveying natural microbial communities in an effort to discover a broader range of enzymes that might more efficiently break down cellulosic biomass. Newly discovered enzymes may be more capable of breaking down the various cell wall components, allowing the pretreatment process to be less harsh and more effective. Two study projects of the BioEnergy Science Center ("BESC") have been searching for new enzymes and microbes to possibly convert cellulosic biomass into biofuel in a single step, called consolidated bioprocessing ("CBP"). Due to cellulosic recalcitrance, any CBP process must include a group of powerful extracellular hydrolytic enzymes that would be stable under the high temperatures likely required for this

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168 See Plant Cell Walls, supra note 64.
169 See Fuel Ethanol, supra note 41.
170 BARRIERS, supra note 62, at 3; Greer, supra note 86.
171 See Greer, supra note 86.
173 Id.
174 Fuel Ethanol, supra note 41.
175 Id.
process. The search has concentrated on thermophilic anaerobes, with *Anaerocellum thermophilum* one microbe that has been tested with switchgrass and hardwood poplar. Through these studies, researchers hope to better understand at the molecular level how cellulosic biomass is degraded, how the mechanisms vary depending on the type of biomass, and how mechanisms vary on specific substrates, such as crystalline cellulose.

**B. Improved Fermentation and Ethanol Recovery**

Biotechnology can also provide possible solutions for improving fermentation to increase ethanol recovery. Two main biological barriers in this area are that the few microorganisms that can ferment both 5- and 6-carbon sugars have lower ethanol production rates, and the organisms capable of fermenting this sugar mix have less tolerance for the ethanol that is produced. Current biotechnology studies are attempting to identify which microbial genes are involved in fermentation so that genetic engineering might lead to the creation of a microorganism that can withstand higher ethanol concentrations or more efficiently ferment all types of sugars produced from cellulosic feedstock. One inventor has already applied for a patent on the “use of microorganisms as ‘biocatalysts’ to convert cellulosic feedstock to usable ethanol.” He is genetically engineering yeast using recombinant strains that encode for xylose metabolism expression. Engineering a microbe that can efficiently ferment sugars at higher temperatures would also be valuable for preventing contamination during the fermentation process.

Consolidated bioprocessing, mentioned previously in Part IV.A., also applies to this area of biotechnology research. Experts believe combining the enzymatic hydrolysis and fermentation processing stages in microbial systems can significantly reduce cellulosic biomass-to-ethanol

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179 Id.

180 Fuel Ethanol, supra note 41.

181 Id.


183 Id.

184 Fuel Ethanol, supra note 41.
Researchers are employing recombinant DNA technology to integrate the hydrolysis and fermentation steps into one microbe or stable mixed culture. For example, an engineering professor at Dartmouth College, Lee Lynd, is attempting to integrate into one organism "cellulose production, cellulose hydrolysis, hexose fermentation and process fermentation." Another study is attempting to construct a "bioprocessor" derived from *Escherichia coli* ("E. coli") that will be capable of completely converting cellulosic biomass to ethanol in one step. Initial steps in this construction involve "the introduction of heterologous genes responsible for cellulose degradation" and the genetic engineering of *E. coli* to allow the expression of "genes encoding the Type II secretory apparatus" necessary for the process. *E. coli* also will be engineered to improve ethanol production efficiency and to improve its tolerance to higher concentrations of ethanol. Finally, an improvement in *E. coli* 's ability to break down the 5- and 6-carbon sugar mixtures remaining from hemicellulose hydrolysis is necessary for a more efficient conversion of cellulosic biomass into ethanol. This study uses both candidate gene approaches and random mutagenesis to enhance this ability.

C. Improving Cellulosic Feedstock

Some biotechnology research involves hybridizing or genetically modifying the crops planted specifically for biofuel use. Because cellulosic biomass can be grown in marginal or surplus land, rather than prime agricultural land, some studies involve broadening the availability of even marginal land through genetic modification of these crops. For example, when the mechanisms that allow certain crops to be tolerant to

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185 Greer, supra note 86.
186 Id.; see also Fuel Ethanol, supra note 41 (noting the importance of identifying and understanding genes that code for fermentative microbes).
187 Id. note 86.
189 Id.
190 Id.
191 Id.
194 See generally BARRIERS, supra note 62, at 8–12 (discussing land availability and potential biotechnological advances to increase biomass crop yields).
cold, to withstand drought, and to withstand salt are understood, biofuel crops could be engineered to be productive in those marginal areas. Studies already underway with plants genetically modified for drought-stress tolerance are yielding positive results, even when plants were subjected to a severe drought.

Another crop modification being studied would increase carbon uptake in cellulosic crops. With biomass crop yield generally defined as "the amount of fixed carbon per acre per year," genetically engineering dedicated energy crops to increase the amount of carbon per cell or the number of cells per acre can increase the biomass yield. One obstacle to this modification, however, is determining how to maximize the photosynthetic fixation of carbon dioxide ("CO\textsubscript{2}") to aid in carbon accumulation. "Plants ... fix only the [amount of] carbon needed for normal growth," even though they have the ability to fix higher amounts. Studying the mechanism that regulates photosynthetic CO\textsubscript{2} and determines carbon uptake could lead to the engineering of plants that routinely fix higher amounts of carbon.

To summarize, biotechnology may provide a way of overcoming the biological barriers to implementing the EISA cellulosic biofuel goals. Genetic manipulation of enzymes is improving the deconstruction of the plant cell wall and the conversion of the hydrolyzed biomass into ethanol. Cellulosic crops are also being genetically engineered to increase carbon uptake and to allow growth in poor soil and climate conditions generally not conducive to plants. Although other obstacles still exist before the biofuel goals in EISA can be reached, the biologic barriers are gradually being addressed with promising results.

VI. LEGAL ANALYSIS: IS EISA THE BEST APPROACH?

EISA is meant to address the various concerns with fossil fuel use and the growing national security concern with our country's dependence on foreign oil. As previously discussed, studies have shown definite benefits from EISA's mandated use of cellulosic biofuel and promising results with the use of biotechnology to overcome potential obstacles. Even so, it could be argued that this legislation either is not a complete

\[\text{id. at 66.}\]
\[\text{id.}\]
\[\text{id. at 64-65.}\]
\[\text{id. at 64.}\]
\[\text{id.}\]
\[\text{id. at 65.}\]
\[\text{id.}\]
\[\text{See generally Duffield, Xiarchos & Halbrook, supra note 13 (discussing the history and implementation of ethanol policies in the United States).}\]
\[\text{See BARRIERS, supra note 62, at 64-66.}\]
answer or is not the best answer for addressing these concerns. These arguments are backed by several valid suppositions, which include: (1) farmers may not be willing to take an economic chance on biofuel-specific cellulosic crops when corn production and government subsidies have brought them such high levels of income in recent years; (2) current levels of government funding are not sufficient for supporting research for conversion and processing techniques, for building prototype biorefineries, and for providing incentives to those pursuing this type of biofuel production; (3) simply increasing fuel supplies with the introduction of more biofuel is not the complete answer—cars need to continually evolve to the point where less fuel of any kind is necessary; and (4) with the current competitive pricing of gasoline, there is really no reason for most farmers or consumers to make the changes that will be necessary to meet EISA biofuel goals. Without a buy-in from the public and farmers, EISA may not provide the most effective approach for accomplishing the national goals of decreasing fossil fuel use and GHG emissions.

A. Acceptance by Farmers

"Thanks in part to biofuels, the economic picture for the U.S. farm sector has never been brighter, with the farm economy witnessing ‘unprecedented increases in income and asset values the past few years.’" Contributing to this above average income for farmers are record high United States’ agricultural exports in 2007 and 2008, good crop yields, and high commodity prices. This boom has also affected many farm assets. A farmer’s most important asset is his land, which often serves as the main source of collateral for loans obtained to finance his business. Due to higher financial returns to farmers, real estate prices have also increased. In addition to these market benefits of corn production, government subsidies provide farmers with incentives to grow corn.

Although this growth in income and assets has greatly benefited farmers and agricultural communities in the United States, it also portends a serious issue with the EISA legislation. To reach the levels of biofuel mandated by EISA, biofuel-specific cellulosic crops must also be produced as feedstock, in addition to feedstock that is already available like corn

204 See Duffield, Xiarchos & Halbrook, supra note 13, at 425.
205 Id. at 444.
206 Greer, supra note 86.
207 See Duffield, Xiarchos & Halbrook, supra note 13, at 450–51.
208 See id. at 451.
209 Id. at 444–44.
210 Id. at 444.
211 Id.
212 Id. (predicting that farm real estate would increase by 14% from 2006 to 2007).
213 AAAS BIOFUELS, supra note 106.
stover, wheat straw, and material from forest clean-ups. With farmers experiencing some of their highest farm income in years, plus the huge benefit of corn subsidies, planting completely new crops with different production methodologies will likely be perceived by farmers as a risky and difficult change. Adding to the risk is the fact that some feedstock crops, such as switchgrass or poplar trees, take several years to mature. A farmer’s return on his investment could be slow in coming.

In much the same way that most policymakers who support grain ethanol legislation serve the “Corn Belt” states, policymakers from areas where farmers could use marginal lands for cellulosic biofuel crops may need to support legislation for their districts. Additional legislation is necessary to provide farmers with subsidies to support them while cellulosic crops mature and with incentives to make the risky switch to cellulosic crops more appealing. Farmers will also want to see proof of the government’s commitment to EISA’s mandates through EISA’s promise of money encouraging the development of cellulosic biorefineries in their area. With no current cellulosic market or infrastructure, farmers have few incentives to grow cellulosic biomass even though it may be the crop of the future.

B. Government Funding

Knowing that research and development are necessary to develop a cellulosic biofuel industry, EISA authorizes $1.2 billion in discretionary funds to be used for research on biomass, bioenergy, and bioproducts. In addition, EISA authorizes discretionary funds of $25 million for renewable energy technology research, $1 million for studying the feasibility of building dedicated ethanol pipelines, and $200 million for biomass-ethanol conversion assistance grants and infrastructure pilot programs. These amounts may still not be enough. A report published by the National Resources Defense Council (“NRDC”) in 2005 stated there is a need for two billion dollars over the next ten years to adequately develop biofuels. Of these funds, $1.1 billion would support research, development, and

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214 See Greer, supra note 86. “Corn Belt” Congressmen are still heavily promoting the corn ethanol industry even though the National Corn Growers Association (NCGA) views EISA’s fifteen billion gallon cap on corn ethanol by 2022 to be the upper limit of corn ethanol that can be produced without severely affecting corn markets for food and feed. Duffield, Xiarchos & Halbrook, supra note 13, at 441, 446–47.
215 Greer, supra note 86.
216 Duffield, Xiarchos & Halbrook, supra note 13, at 441.
217 See KELSI BRACMORT ET AL., CONG. RESEARCH SERV., RL 34738, CELLULOSIC BIOFUELS: ANALYSIS OF POLICY ISSUES FOR CONGRESS 1–8, 12–14 (2010).
218 CAPEHART, SCHNEPF & YACOBUCI, supra note 2, at 9.
219 Id. at 11.
220 Greer, supra note 86.
demonstration projects for conversion and processing technologies.\textsuperscript{221} Another $800 million would support the development of biorefineries.\textsuperscript{222} Although EISA authorizes the DOE to help fund the building of commercial biorefineries for cellulosic biomass, more funds likely will be necessary to support studies on various refinery designs and to aid in the building of small-scale refineries to test those designs.

One significant area for which EISA has not authorized funding is the support of innovative incentives for the deployment of cellulosic biofuel. Because of the risks involved in switching to biofuel-specific cellulosic crops and in developing new, never-used conversion and production technologies, the typical performance-based incentives may not be as effective in encouraging participation.\textsuperscript{223} Bond and efficacy insurance have been suggested as government incentives for this industry, as a substantial barrier for those entering the cellulosic biofuel industry might be the difficulty in arranging necessary financing.\textsuperscript{224} Those involved in feedstock supply or biofuel purchasing would be able to select bond insurance to make them creditworthy to financiers.\textsuperscript{225} For developers involved in conversion and production of biofuel, efficacy insurance would pay for technology failures not associated with mistakes or equipment breakdown.\textsuperscript{226} Developers might also have the option of turning their insurance incentive into a production incentive to be paid out over the first five years if production levels meet or exceed set goals.\textsuperscript{227} To provide these incentives, the government would need to either induce private insurance companies to offer these types of insurance for the cellulosic industry or offer the policies itself.\textsuperscript{228}

C. Increasing the Biofuel Supply: Only Part of the Answer

The research currently being done on cellulosic biomass to decrease conversion costs and increase conversion efficiency undoubtedly plays a major role in reaching EISA-mandated biofuel production and use goals. EISA may not, however, provide a complete answer to fully meeting the goals of deceased GHG emissions and decreased dependence on oil. With no improvement in gas mileage and with consistent growth in the

\begin{footnotesize}
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  \item \textsuperscript{221} Id.
  \item \textsuperscript{222} Id.
  \item \textsuperscript{223} NATHANAEL GREENE ET AL., NAT'L RES. DEF. COUNCIL (NRDC), GROWING ENERGY: HOW BIOFUELS CAN HELP END AMERICA'S OIL DEPENDENCE 15 (2004), available at \url{http://www.nrdc.org/air/energy/biofuels/biofuels.pdf}. An example of a performance-based incentive would be a tax credit tied to the amount of biofuel produced. CAPEHART, \textit{supra} note 66, at 18.
  \item \textsuperscript{224} GREENE ET AL., \textit{supra} note 223, at 16.
  \item \textsuperscript{225} Id. at 16.
  \item \textsuperscript{226} Id. at 16–17.
  \item \textsuperscript{227} Id. at 17.
  \item \textsuperscript{228} See id.
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amount of driving done by Americans, the United States will “consume 290 billion gallons of gasoline . . . by 2050,” compared with about 140 billion gallons consumed annually today. Nathanael Greene, author of the *Growing Energy* report published by the NRDC, stated that “[i]f we are serious about ending our dependency on oil, we need to innovate and change. . . . We are kidding ourselves if we think we can supply our way out of this.”

A major concern with only increasing the supply of alternative fuels, rather than also acting to decrease fuel use, is the slow evolution from fossil fuel to biofuel use, particularly future cellulosic biofuel use. This slow evolution is due in part to obstacles previously discussed in this Article—issues with the conversion of cellulosic biomass into ethanol and the lack of any infrastructure for cellulosic biofuel. Even with current research searching for solutions to these problems, it will be a number of years before solutions will be fully implemented, with at least one source suggesting it will be at least three to five years before we first start seeing cellulosic biofuel use. In the meantime, the NRDC recommends pushing for increased vehicle efficiency, such as government mandates for vehicle efficiencies of at least fifty miles per gallon.

**D. Mandates vs. Carbon Fuel Tax or Cap-and-Trade**

In much the same way farmers have little incentive to switch to biofuel-specific cellulosic crops, the current competitive pricing of oil provides no impetus for consumers to decrease their use of fossil fuels and make the switch to biofuels. When gasoline prices are low, gasoline use generally rises, with most consumers not giving any thought to the level of GHG emissions associated with its use. Even when EISA mandates result in greater availability of biofuel-gasoline blends, some argue this will lead to even higher fossil fuel use. Society may view the addition of larger amounts of biofuel to the fossil fuel supply as evidence the fuel supply is plentiful, sustainable, better for the environment, and locally produced. Reasons to be cautious about fuel consumption may not be readily apparent. Because of this potential outcome, some suggest that although the EISA

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229 Greer, *supra* note 86.
230 Duffield, Xiarchos & Halbrook, *supra* note 13, at 446.
231 Greer, *supra* note 86.
233 Greer, *supra* note 86. (explaining that “increasing vehicle efficiencies to 50 mpg or better and instituting smart growth policies could reduce consumption to 108 billion gallons by 2050”).
234 Madhu Khanna, Professor, Dept. of Agric. & Consumer Econ., Univ. of Ill. at Urbana-Champaign, Presentation at the U.S. Dep’t of Energy, Genomics: GTL Awardee Workshop VII and USDA-DOE Plant Feedstock Genomics for Bioenergy Awardee Workshop 2009: Land Use and Carbon Impacts (Feb. 9, 2009).
biofuel mandates are a positive first step, additional legislation, likely in the form of a carbon tax or cap-and-trade legislation, will be necessary to help mitigate GHG emissions and fossil fuel use.\textsuperscript{235} The concept behind a carbon tax is to modestly tax each ton of emissions initially and gradually increase the tax each year until the decrease in GHG emissions reaches a set goal.\textsuperscript{236} All greenhouse gases released by burning fossil fuels, such as gasoline, diesel, natural gas, coal, heavy fuel oil, propane, or kerosene, would be taxed.\textsuperscript{237} The expected outcome is that higher fossil fuel prices will decrease the amount purchased and increase the use of alternative energy sources and the purchase of biofuel-gasoline blends for vehicles. Government leaders will likely be unwilling to push for billions in new taxes during this economically stressful time, regardless of the fact the carbon tax would be revenue neutral.\textsuperscript{238} Although the alternative cap-and-trade system would result in the same higher energy prices as a carbon tax, cap-and-trade does not use the word “tax,” which “makes people choke [even] in normal times[,] [a]nd these are not normal times.”\textsuperscript{239}

Although President Obama and other Democratic leaders are pushing for the cap-and-trade system, the new energy bill unveiled in the Senate in July 2010 lacked the hoped for cap-and-trade provision.\textsuperscript{240} Like a carbon tax, a cap-and-trade system must also cover all measurable GHG emissions from any carbon based fuel, particularly gasoline and diesel.\textsuperscript{241} A cap-and-trade system first establishes a mandatory “cap” on GHG emissions, the maximum emissions our economy can produce each year, and then auctions permits that allow companies to emit GHG.\textsuperscript{242} Because this system functions at the point where fossil fuels enter the economy of the state or nation, less than one-tenth of one percent of businesses would interact with a cap-and-trade system.\textsuperscript{243} Also, there is no paperwork, such as permits, necessary for families or small businesses.\textsuperscript{244} The “trade” piece of the system comes in when companies “trade” their GHG emission

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\item Id.
\item \textsc{Alan Durning} \textsc{et al.}, \textsc{Sightline Inst.}, \textsc{Cap and Trade 101: A Climate Policy Primer} 28–29 (Jan. ed. 2009), available at http://www.sightline.org/research/energy/res_pubs/cap-and-trade-101/Cap-Trade_online.pdf.
\item Broder, supra note 236, at A13.
\item Id.
\item Durning \textsc{et al.}, supra note 237, at 4.
\item Id. at 4, 6.
\item Id.
\item Id.
\end{enumerate}
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permits with each other. The permission to pollute becomes a commodity that is bought and sold, which, in theory, encourages businesses and individuals alike to find ways to decrease their GHG emissions.\textsuperscript{245} Revenue from auctioning the cap-and-trade permits is intended to support the development of new technology, such as solar power, wind power, and advanced biofuel production.\textsuperscript{246}

In summary, EISA is important in its role of addressing issues with dwindling fossil fuel supplies and the United States’ dependence on foreign oil, along with enhancing revenue for rural areas. It may not, however, be able to accomplish fully its goals of reducing fossil fuel use and GHG emissions without further legislation providing assistance. To ensure that EISA moves forward at the pace outlined in the legislation, the government must address the need for additional funding crucial for creating a cellulosic biofuel infrastructure and incentive programs to counter the risk of entering this new industry.

VII. CONCLUSION

Due to continuing concerns about decreasing oil availability and the nation’s growing dependence on foreign oil, Congress passed the Energy Independence and Security Act of 2007. This Act mandates several actions intended to promote the research, development, and use of biofuels, particularly “advanced” biofuels.\textsuperscript{247} One mandate raises the requirement for biofuel production to thirty-six billion gallons of biofuel produced annually by 2022 as compared to the 8.6 billion gallons previously required in the EPAct.\textsuperscript{248} Another mandate caps the ethanol produced from corn and other grains at fifteen billion gallons and requires no less than twenty-one billion of the thirty-six billion gallon biofuel total to be “advanced” biofuel.\textsuperscript{249}

Many benefits are anticipated as a result of the mandated cellulosic biofuel production goals. These include decreased dependence on foreign oil and development of a local, sustainable fuel supply. Potential positive environmental impacts result from decreased GHG emissions, decreased soil erosion, and less use of fertilizer, pesticide, and herbicide. There are, however, certain obstacles that must be addressed in order to reach the optimistic goals of EISA. Although these obstacles include the lack of an adequate infrastructure and of automobiles capable of using fuel with higher ethanol-to-gasoline ratios, the most significant barriers are the biological barriers encountered with the use of cellulosic biomass. Biotechnology techniques appear to be the most promising for addressing

\textsuperscript{245} Id. at 6.
\textsuperscript{246} Samuelsohn, supra note 240.
\textsuperscript{247} CAPEHART, SCHNEPF & YACOBUCCI, supra note 2, at 5.
\textsuperscript{248} CAPEHART, SCHNEPF & YACOBUCCI, supra note 2, at 1.
\textsuperscript{249} Duffield, Xiarchos & Halbrook, supra note 13, at 439.
these barriers. Studies are already underway that look to gene modification and engineering of cellulosic feedstock, microbes, and enzymes to decrease the recalcitrance of cellulosic biomass, improve the fermentation process for a higher ethanol yield, and alter cellulosic crops.

In evaluating the future success of EISA, it is important to consider whether EISA’s mandates fully accomplish its overall legislative goals. For example, the goals of decreasing GHG emissions and fossil fuel use may require additional legislation, such as carbon fuel taxes or the implementation of a cap-and-trade system, as incentives to consumers to decrease fuel use. Also, additional legislation will undoubtedly be necessary to fund the essential cellulosic biofuel infrastructure and to develop incentive programs that encourage farmers and biorefinery developers to take the risk of entering this new biofuel industry. If these possible areas of concern are addressed early, EISA should have no problem moving forward at the pace outlined in the legislation.