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Growing Complexities: A Cross-Sector Review of U.S. Biofuels Policies and Their Interactions

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RESOURCES FOR THE FUTURE

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Abstract

In the midst of concerns about U.S. energy security and climate change, a wider use of biomass and biofuels is promoted as one of the recipes for sustainability. The production and use of biofuels in the United States has rapidly increased in the last several years, promoted by a variety of government policies at the federal, state, and even local level. Many of these policies were crafted with focused objectives in mind and are targeted at specific segments of the biofuels market. Little is known, however, about the potential interactions of such policies and whether they are likely to reinforce or negate one another.

In this paper, we provide an overview of the most prominent policies to date that impact the production and use of biofuels and biomass and outline their intended objectives and mechanisms. We focus on three economic sectors, electricity, transportation, and agriculture, and conduct a qualitative analysis of selected policy interactions. In particular, we describe hypothetical policy scenarios corresponding to various combinations of policies and analyze their potential outcomes. Finally, we briefly describe the impacts of those policies on other sectors such as food production, energy and environment, infrastructure, and the economy at large.

Key Words: transportation sector, electricity sector, agriculture, policy analysis, biofuels, biomass, ethanol, policy review

JEL Classification Numbers: C61, C68, D58, Q11, Q18, Q20, Q40, R41, R48

Contents

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Introduction

Biofuels have recently become a large part of the national dialogue on energy policy. These fuels, created from various forms of organic matter instead of traditional petroleum products, are seen as an energy source that can both mitigate climate change by reducing greenhouse gas (GHG) emissions and improve domestic energy security by reducing oil dependence. The U.S. government has long supported biofuels with various credits and subsidies, but in 2005 major legislation was passed to significantly promote their production and use. As biofuels continue to become increasingly important, several previously unanticipated consequences of large-scale production have also emerged. Understanding and managing these consequences requires improved analysis of the direct and indirect effects of biofuels policies and their interactions.

The biofuels industry has recently been subject to intense scrutiny because of the countless policies that influence the wide variety of biofuels. The term biofuels is often used to describe any fuel derived from an agricultural product. This includes dedicated biomass crops, agricultural residues, and urban wood waste or forestry residues used to generate electricity as well as transportation fuels, such as ethanol refined from corn or other crop cellulose and biodiesel made from soybeans.

This paper deals directly with two categories of biofuels used in the United States: 1) ethanol refined for transportation and 2) biomass crops used to generate electricity. At present, the main type of biomass used for ethanol is corn, while agricultural residues that are burned together with coal (called co-firing) comprise the main source of biomass used to generate electricity. Although corn is the primary biomass product used to date, new biofuels development is expected to shift biofuels toward cellulosic ethanol, or ethanol made from nonedible plants and crop residues. Cellulosic technology is still in early research and development stages, but both policy and industry incentives in this area can potentially change

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the shape of the U.S. biofuels market altogether. Electricity generation facilities that burn pure biomass are also being developed for commercial use. Both of these technologies could take advantage of dedicated biomass crops, such as perennial grasses called switchgrass that could be grown explicitly for biofuels production. Given these new areas of growth, the biofuels industry is still rapidly evolving. Understanding the role of policy in this evolution requires careful integrated policy analysis.

Currently much of the research on biofuels is fragmented across academic disciplines, industry sectors, or policy applications. In contrast, the implementation and impacts of early biofuels policy have revealed the importance of key interactions across sectors, particularly transportation, agriculture, and electricity. For example, biofuels policies in the U.S. transportation sector to date have been criticized for driving up food prices. Similarly, European Union policies have been blamed for deforestation in developing countries such as Indonesia.

While the transportation and electricity sectors use biofuels differently, these sectors are both closely linked through the agriculture sector that provides the biomass supply necessary for biofuels. Even if these sectors do not compete for the same biomass products, both sectors place demands on limited agricultural land resources across the country. Biofuels can also put stress on other sectors that require agricultural products, such as livestock and other grain markets. Therefore, policies primarily focused on one sector will inevitably have consequences for others.

As the biofuels industry receives greater attention in both research and practice, the potential far-reaching impacts of biofuels policies make their direct and indirect outcomes particularly difficult to analyze. The interactions among the agriculture, transportation, and electricity sectors create effects that cannot be looked at from the perspective of any one sector. A policy aimed at increasing ethanol production for transportation, for example, will undoubtedly affect biomass use in the electricity sector, thereby influencing incentives for biomass production in the agriculture sector. These interactions have the potential to be even greater and farther reaching when biofuels policies exist in all three sectors simultaneously.

While every policy has multiple primary objectives, these aims could be undercut by parallel or future programs with competing objectives. A host of unintended consequences could result from cross-sectoral interactions and indirect effects. Some provisions within policies might even duplicate or negate provisions in other sectors as the latter compete for limited resources.

Several papers have catalogued and addressed the goals of biofuels policies, but these review documents typically provide policy summaries without any critical analysis of potential interactions. For example, (Yacobucci 2008b) catalogues and summarizes U.S. biofuels programs and incentives by federal department. Another Congressional Research Service report (Yacobucci 2007) breaks biofuels policies down by sector but does not discuss how the policies might interact.

Recent research studies have attempted to describe interactions between two sectors, such as (Sexton, Rajagopal et al. 2008), who address basic interactions between the energy and agriculture sectors. Their analysis, however, fails to address how competing demands for biomass could interact across all three sectors simultaneously. Even broader evaluations focus on food prices, environmental concerns, and infrastructure issues related to biofuels policy but do not address multisector interactions or their impacts. Although biofuels analyses are slowly becoming broader and thus able to capture and evaluate the effects of the full policy landscape, they often overlook cross-sectoral biofuels policy interactions.

This paper lays the groundwork for an integrated analysis that seeks to capture these important cross-sectoral interactions and their broader impacts. By carefully reviewing biofuels policies in the agriculture, transportation, and electricity sectors and highlighting their primary aims and objectives, potential cross-sectoral interactions, and their possible larger impacts, we aim to refocus the lenses through which biofuels policies are currently viewed and analyzed. Ultimately, the goal of this paper is to gain a better qualitative understanding of how biofuels policies interact across sectors and to create a framework through which the magnitude of these impacts can be further quantitatively evaluated.

To this end, this paper is organized into three main sections: primary policy objectives, secondary policy interactions, and tertiary policy impacts. The goals of this paper are threefold. First, we provide a basic review of major biofuels policies enacted to date. Second, we develop a framework for critical qualitative analysis of major policy interactions. Finally, we place this analysis in a larger context by discussing the macro effects of biofuels policies.

The primary objectives section builds on the work of other scholars who have documented the goals and potential impacts of specific pieces of biofuels policy legislation. The secondary policy analysis highlights key interactions, with a particular focus on the potential outcomes if policies are enacted simultaneously in various combinations. This section moves beyond a traditional policy review to evaluate the cross-sectoral effects that could otherwise be overlooked in a purely primary objectives analysis and lays the groundwork for further quantitative modeling and analysis of biofuels policies.

Finally, it is also important to study the larger effects of biofuels policies beyond the agriculture, transportation, and electricity sectors. Many of these global economic and environmental impacts have been more widely studied than secondary policy interactions to date. Therefore, our final tertiary impacts section describes some of the broader analyses of the role of biofuels in mitigating climate change and improving energy security. This section also captures the large-scale changes to infrastructure and other aspects of the economy and environment that could result from primary policies and their interactions. Overall, the tertiary impacts section helps place biofuels sectors and their respective policies in a larger context and discusses impacts beyond the scope of the primary objectives and secondary interactions sections.

While all three sections highlight different aspects and scales of biofuels policies, together they are intended to provide a comprehensive picture of interactions across the policy landscape and establish a framework for more detailed analysis by using a novel nested perspective and approach.

Primary Policy Objectives

Biofuels policies to date have been concentrated in the agriculture, transportation, and electricity sectors. The following sections describe the most prominent and potent policy features of these sectors and their intended aims.

Agriculture Sector

Agricultural policies in the United States affect all aspects of the agriculture industry. Policy goals range from price stabilization and support to food assistance, environmental conservation, international trade, marketing, and rural development (Womach, Becker et al. 2007). Some of the defining parts of farm legislation focus on commodity price support policy that describes how and at what level the government will support agricultural production. These policies are up for renewal every four to six years in an omnibus “Farm Bill” that updates relevant programs and addresses new issues facing the agriculture industry (Womach, Becker et al. 2007). Currently, many of these new programs focus on the growing demand for biomass in the electricity and transportation sectors. In the following subsections, we briefly review three main agricultural policies and programs: ethanol tax credits and tariffs, the Conservation Reserve Program (CRP), and the Biomass Crop Assistance Program (BCAP).

Ethanol Tax Credits and Tariffs

Many agricultural policies directly impact the supply of biofuels. The most influential pieces of legislation to date determine how ethanol is produced through ethanol tax credits and tariffs. Ethanol producers currently receive a \$0.45/gal tax credit for corn ethanol and \$1.01/gal for cellulosic ethanol (Yacobucci 2008b).[1] This price support significantly helps U.S. ethanol producers compete in transportation fuel markets. The ethanol tax credit, which was first introduced in 1978 under the energy Tax Act, is crucial to the functioning of the ethanol industry. Gasohol, the first commercial gasoline–ethanol blend, was first defined as containing at least 10 percent ethanol and was given a $0.04/gal tax credit (equivalent to $0.40/gal credit on ethanol). Since then the value of this credit has varied, and ethanol refiners and blenders started receiving credit for gasohol blends of less than 10 percent (Tyner 2008).

Domestic producers are also protected from foreign ethanol competition by a 2.5 percent import tariff and an additional $0.54/gal tax. [2] The tax credit and tariff work together to create a protected domestic market. Both were created in 1980 to offset the tax credits and have since worked to protect the ethanol market from foreign competition.[3] The only exception is that Caribbean Basin Initiative (CBI) countries can supply up to 7 percent of U.S. ethanol duty free (Yacobucci 2008c).[4]

Conservation Reserve Program (CRP)

Direct credits and tariffs are significant in the biofuels market, but there are also many other policies that influence the supply of biomass and the agriculture sector. The CRP pays farmers to take environmentally sensitive land out of production for 10- to 15-year periods (Cowan 2008). Program goals include price stabilization in times of excess supply and protection of marginal lands from overproduction. Farmers receive on average $51/acre for enrolling their land in the program. Higher premiums are given to projects of special interest, such as the Conservation Reserve Enhancement Program, which targets areas with serious agriculture-related environmental problems (Cowan 2008).[5]

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[1] These rates take effect in 2009. Under the 2002 Farm Bill both types of ethanol received a $0.51/gal credit (Yacobucci 2008b).

[2] The tariff is structured as an ad valorem tariff, which is important because Brazilian sugarcane ethanol is currently produced at significantly lower costs. Some Caribbean countries under the Caribbean Basin Initiative (CBI) can also import ethanol duty free (Yacobucci 2008c).

[3] Brazil is the main country that would be able to export ethanol to the United States if tariffs were removed (Yacobucci 2008c).

[4] CBI countries include all countries on the Caribbean Sea. Usually this ethanol is produced in Brazil, and only the last step (usually dehydration) is done in a CBI country to avid the tariff (Yacobucci 2008c).

[5] Projects include Maryland's Chesapeake Bay and Florida's Everglades. There are around 1.1 million acres in the program (USDA Farm Service Agency 2007).

The CRP has been credited with improving soil quality across the country. It has been estimated that compared with historical erosion rates, 454 million tons of erosion were prevented on the 34.6 million acres of enrolled land.[6] The CRP has also restored 2.5 million acres of buffer wetlands and sequestered 48 million tons of carbon (Cowan 2008). While the benefits of the CRP have been widely acknowledged, the program has also been heavily criticized in times of high demand for agricultural land, because farmers who enroll their land in the program have to wait for their contracts to expire to use their land for agricultural production. Although it is possible to withdraw land early from the program, the penalties for doing so are steep. Farmers are forced to return all payments received with interest and in addition pay a penalty equal to 25 percent of all payments received while enrolled (Cowan 2008).[7]

Biomass Crop Assistance Program (BCAP)

The CRP has been in place since 1985, and while it does not deal directly with biomass production, it has the power to affect the biomass market by placing additional constraints on land use. Another more recent program passed into law to directly target biofuel crops and farmers is The Biomass Crop Assistance Program (BCAP), designed to provide up to 75 percent of the costs associated with converting land to production of an approved biomass crop.[8] The goal of the program is to reduce the capital costs of transitioning to biomass production. The rationale behind this program was that biomass could be an economically viable source of revenue for farmers, but that the transaction costs associated with changing crops would limit the production of biomass in the near future (USDA Economic Research Service 2008).

BCAP contains other incentives to help farmers produce biomass. The legislation states that for the first two years of production, BCAP provides matching funds for up to $45/ton of the costs associated with the harvest, storage, and transportation of raw biomass to a biofuel refinery. After the first two years, annual payments will continue indefinitely.[9] All of these details were laid out in the Farm Bill of 2008, but the program has yet to be funded in the Congressional budget or implemented, and no studies have estimated its potential effects as yet (Yacobucci 2008b).

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[6] The 2008 Farm Bill drops total enrollment to 32 million acres (Cowan 2008).

[7] Recently there has been a large demand to eliminate these penalties due to increasing corn prices, but this request was denied in July 2008 (Schafer 2008).

[8] Rules have yet to be defined for what is an approved crop.

[9] The amount of these payments has yet to be determined (USDA Economic Research Service 2008).

Transportation Sector

The transportation sector is a large source of biomass demand in the U.S. economy. Ethanol has existed as a fuel additive to reduce emissions since the mid-1990s and has been blended into reformulated gasoline at low levels[10] in certain pollution “nonattainment” areas (Yacobucci 2007).[11] Recently, biofuels have come into the spotlight as a domestically produced petroleum replacement that can potentially reduce U.S. dependence on foreign oil. One of the primary policies used to encourage the production and use of ethanol is the Renewable Fuel Standard (RFS), which mandates gasoline blenders to use a specific percentage of ethanol or face penalties for noncompliance.[12] In the next subsections, we discuss two major biomass-related transportation policies: the RFS and the Corporate Average Fuel Economy (CAFE) standard.

Renewable Fuel Standard (RFS)

The first RFS was passed as part of the Energy Policy Act of 2005. This standard requires that a specific volume of ethanol is refined and blended into the total U.S. supply of gasoline. Each year, the standard is increased incrementally with differentiated requirements for corn and cellulosic ethanol. The standard set in 2005 required 7.5 billion gallons of corn ethanol and 250 million gallons of cellulosic ethanol to be produced in 2012. These levels, however, were not projected to be binding since models and forecasts show that 11.2 billion gallons of ethanol would be produced in 2012 under business as usual (BAU) assumptions (Energy Information Administration 2007a).

In 2007, the Energy Independence and Security Act (EISA2007) updated the RFS with higher mandates for ethanol production. This new mandate (Figure 1) differs from the original RFS in three key ways. First, the new levels required are significantly higher than the older ones. Second, it extends the time horizon to 2022. Finally, it increases the total requirements for cellulosic ethanol production (Yacobucci 2008b).

[10] Ethanol works as an oxygenate, which results in more compete combustion of gasoline and reductions in harmful emissions (Yacobucci 2007).

[11] Methyl tertiary butyl ether (MTBE), which was initially the fuel additive of choice, has been phased out over the last 10 years and banned by several states because it was found to contaminate groundwater. Ethanol was the main oxygenate used to replace MTBE (Energy Information Administration 2006).

[12] These requirements are enforced on blenders through a complex system of renewable fuel permits that affect the entire refinery sector.

Figure 1. Annual Increases in RFS-Mandated Biofuels Production, 2006–2022

The applicable volumes, in billions of gallons, under RFS2 are as follows:

Year	Cellulosic Biofuel	Biomass-Based Diesel	Other Advanced Biofuel[1]	Total Advanced Biofuel	Other Biofuel[2]	Total Renewable Fuel
2006					*4.0*	**4.0**
2007					*4.7*	**4.7**
2008					*9.0*	**9.0**
2009		0.5	*0.1*	0.6	*10.5*	**11.1**
2010	0.10	0.65	*0.2*	0.95	*12.0*	**12.95**
2011	0.25	0.8	*0.3*	1.35	*12.6*	**13.95**
2012	0.50	1.0	*0.5*	2.0	*13.2*	**15.2**
2013	1.00	1.0	*1.75*	2.75	*13.8*	**16.55**
2014	1.75	1.0	*2.0*	3.75	*14.4*	**18.15**
2015	3.00	1.0	*2.5*	5.5	*15.0*	**20.5**
2016	4.25	1.0	*3.0*	7.25	*15.0*	**22.25**
2017	5.50	1.0	*3.5*	9.0	*15.0*	**24.0**
2018	7.00	1.0	*4.0*	11.0	*15.0*	**26.0**
2019	8.50	1.0	*4.5*	13.0	*15.0*	**28.0**
2020	10.50	1.0	*4.5*	15.0	*15.0*	**30.0**
2021	13.50	1.0	*4.5*	18.0	*15.0*	**33.0**
2022	16.00	1.0	*5.0*	21.0	*15.0*	**36.0**

Source: Energy Independence and Security Act of 2007 (HR 6)

Note: Values in *italics* calculated from RFS values as found in the 2007 Act.

[1] Other Advanced Biofuel = Advanced Biofuel – Cellulosic Biofuel – Biomass-Based Diesel

[2] Other Biofuel = Total Renewable Fuel – Total Advanced Biofuel

Source: (U.S. EPA 2008)

Under the 2007 standard the corn ethanol requirement starts at 9 billion gallons in 2008[13] and increases to 15 billion gallons in 2015, after which all additional ethanol must come from cellulosic and other advanced sources of biomass.[14] This is a noteworthy cap since it could represent an upper bound on corn ethanol production in the near future (Yacobucci and Bamberger 2007).

In contrast, cellulosic ethanol, which has a 16-billion-gallon requirement by 2022, is a relatively unknown quantity at present. While some think that it will become commercially viable in the near future, there is little certainty (Yacobucci and Bamberger 2007). Government projections show that we will not be able to meet the cellulosic ethanol demand required by the RFS and that changes will need to be made to the standard levels (Energy Information Administration 2008a).[15] The most recent projections show that the 2022 RFS mandates will not be satisfied until 2030 (Energy Information Administration 2008b).

Corn and cellulosic ethanol remain the most important categories of fuels under the RFS, comprising 31 of the 36 billion gallons mandated in 2022. The other two categories, biodiesel and other advanced biofuels, are planned to take effect further in the future, and the impacts have yet to be determined (Yacobucci and Bamberger 2007).

Corporate Average Fuel Economy Standard (CAFE)

The CAFE standard is a set of guidelines placed on the automobile industry to govern fleet-wide fuel economy. CAFE was created in 1975 in reaction to the Arab oil embargo of 1973–1974 and the subsequent high oil prices. Since then, this standard has continued as a mechanism through which fuel efficiency is federally regulated. The CAFE standard was recently increased by EISA2007. Auto companies are now required to reach a combined 35 miles per gallon (MPG) for their passenger automobile and light truck fleets by 2020. This will be done by incrementally increasing the standard over the next 12 years. Passenger fleets will be

[13] As opposed to the 5.4-billion-gallon requirement for 2008 in the previous legislation (Yacobucci and Bamberger 2007)

[14] The other two categories under the RFS are biodiesel and other advanced biofuels. The other advanced biofuels requirement is an undifferentiated category that can be satisfied by cellulosic ethanol, biodiesel, or some other non-corn ethanol biofuel meeting the required criteria (Yacobucci and Bamberger 2007).

[15] Under EISA2007, the EPA administrator may reduce or waive mandates if he or she believes it is warranted by the current state of the industry. This provision, however, is not well described and cannot be enacted before 2016 (Energy Information Administration 2008a).

required to average 31.2 mpg by 2011 and 35.7 mpg by 2015. Light trucks must meet a lower standard of 25.0 and 28.6 by the same years (Yacobucci 2008a).

Car companies, however, are only required to meet 92 percent of the standards stipulated by CAFE through direct fuel economy reductions. The remaining 8 percent can be met by using flexible-fuel vehicle (FFV) credits or credit trading. FFVs are cars with stock modifications that allow them to burn any combination of gasoline and ethanol. In the previous form of legislation (before EISA2007) the production of FFVs could generate up to a 1.2 MPG credit, allowing manufacturers to obtain the lower MPG requirements then set under CAFE.[16] The credit is intended to reduce GHG emissions through the use of renewable fuels; however, in practice only 1 percent of the fuel used in existing FFVs was ethanol, while the remaining was conventional gasoline (U.S. Department of Transportation, U.S. Department of Energy, and U.S. Environmental Protection Agency 2002).[17] The FFV credit program has been described as increasing overall gasoline consumption since it allows vehicle manufacturers to attain lower fleet MPG ratings while not actually requiring the use of ethanol blends (U.S. Government Accountability Office 2007b).[18] Currently there are around seven million FFVs on the road (U.S. Department of Energy EERE 2008b).[19] However, as programs such as the RFS influence the amount of ethanol produced, the FFV CAFE credit could become increasingly important.[20]

Electricity Sector

The electricity sector relies on a number of generation technologies to provide power to the United States. Most electricity is generated by using fossil fuels, such as coal and natural gas, and nuclear power. Renewable energy, while currently attracting a lot of public attention, only

[16] New credit levels should be released once new CAFE rules are released.

[17] Since 2002 consumption has most likely increased, but the total level remains low (U.S. Government Accountability Office 2007c).

[18] This can also be done at a relatively low cost, since it costs between $30 and $300 for a car manufacturer to install a flex-fuel system (U.S. Government Accountability Office 2007c).

[19] This is compared to 230 million gasoline and diesel vehicles (Yacobucci and Bamberger 2007).

[20] One of the new elements of EISA2007 is that new vehicles will be rated on attribute-based standards. More specifically, a footprint standard will be used that calculates desired fuel economy based on the square feet under the car. The effects of this new standard are unknown until the footprint standard curves are released by the National Highway Traffic Safety Administration (Yacobucci 2008a).

produced 2.4 percent of U.S. power in 2006 (Energy Information Administration 2008c).[21] This is not to say that biomass is not an important source of electricity. As renewables become increasingly important in the United States, biomass is projected to have some of the largest gains in new generation capacity compared with other sources of renewable energy (Energy Information Administration 2008a). The next subsections cover two primary biomass-related electricity policies: state- and national-level Renewable Portfolio Standards (RPSs) and the Federal Renewable Energy Production Tax Credit.

Renewable Portfolio Standard (RPS)

One policy option to increase the amount of renewable energy generated in the United States is through RPSs. At the state level these standards mandate that a certain percentage of a state's electricity must be generated by using specified renewable resources (Rabe 2006). These standards usually establish broad goals, such as generation of 20 percent renewable electricity by 2025, and then the corresponding requirements are phased in over time (Wiser, Porter et al. 2005). As of November 2008, 29 states have passed RPSs, but there is no national standard in place (DSIRE 2008b). Proposals for a national RPS have been put forward as part of larger bills in Congress on multiple occasions, but they have yet to pass (Vajjhala, Paul et al. 2008).

In setting these standards, some states focus on specific types of renewable energy. Delaware, for example, requires that while 20 percent of the state's generation must come from renewable sources by 2019, 2 percent of the total must use solar resource (DSIRE 2008b). Outside of these resource-specific requirements, a RPS allows for flexibility in which renewable resources are used to meet the standard. Biomass generation is not directly mandated by any RPS, but given the breadth and levels of current RPSs, it is likely to play an important role in most regions of the United States. For example, the southeast region's renewable resource potential is primarily biomass (Sissine 2007a).

Renewable Electricity Production Tax Credit

Production tax credits (PTCs) are another mechanism used to increase renewable electricity generation. Unlike RPSs, which mandate specific levels and types of renewables, the PTC makes renewable electricity more competitive with traditional sources by granting tax

[21] This figure does not include hydroelectric power. Total renewable generation including hydroelectric represented 9.5 percent of U.S. power in 2006 (Energy Information Administration 2008c).

credits to renewable energy producers.[22] The PTC is typically a very potent policy, and biomass, like other sources of renewables, stands to greatly benefit.

Credits are granted on a per kilowatt-hour (KWH) basis, and biomass is divided into two categories for open- and closed-loop biomass generation. Open-loop refers to waste biomass generated from various industrial processes that was not originally intended for electricity use. Closed-loop is all biomass grown for the express purpose of electricity generation. Closed-loop biomass was added to the PTC in 2004; its producers receive a 2.0¢/kWh credit. Open-loop was introduced a year later and receives a 1.0¢/kWh credit (DSIRE 2008a).

The PTC is considered by many to be an effective method to promote the use of renewables (Fischer and Newell 2008; Vajjhala, Paul et al. 2008), but it has been met with many political complications. Lawmakers have historically been reluctant to pass the credit for longer than one or two years. Instead, the policy is renewed intermittently and sometimes even allowed to expire before being passed again. This has created much uncertainty in the renewable energy industry and has shaped investment in energy facilities (Fischer and Newell 2008).

Recently, the PTC was extended through the end of 2009, and biomass was given an extension through the end of 2010 (DSIRE 2008a).[23] This extension covers all facilities put into service before 2011 and provides a tax credit to these facilities for a 10-year period from their beginning date of operation. This gives future biomass investment slightly more certainty and a longer window for planning investment compared to other renewables that received only a one-year extension.

Secondary Policy Interactions

The majority of research done on biofuels to date focuses on one sector and/or one form of biomass. Policies are typically analyzed in the primary sense, as defined in this paper, with a focus on the objectives of individual pieces of legislation. While these studies are important, they can easily miss large effects that a policy might have across multiple sectors. This is particularly important when different sectors have their own biofuels-related policies. If analyses do not

[22] The eligible renewable sources include landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, refined coal, Indian coal, and small hydroelectric (DSIRE 2008a).

[23] Geothermal, hydropower, landfill gas, and waste-to-energy facilities were also included under the 2011 extension (DSIRE 2008a).

allow for cross-sectoral interactions, effects can be missed, and the wider environmental and economic impacts of multiple policies would remain poorly understood.

The primary purpose of this paper is to evaluate biofuels policies from a cross-sectoral perspective to highlight critical interactions. This qualitative analysis looks at the extent to which various cross-sectoral policy interactions are relevant and serves as an important first step toward identifying unintended direct and indirect effects. More specifically, the secondary interactions section outlines how the primary policies described above could drive large-scale crosscutting economic and environmental change when implemented together. To effectively understand these connections, we take a scenario-based approach to describe various combinations of policies and their potential interactions. This approach allows for a qualitative analysis of important combinations of selected policy levers. The scenarios provide insight into how each policy builds on others and what the marginal effects could be of including additional biomass policy provisions.

When trying to isolate the interactions between policies, it is important to carefully define the scope of the analysis. Some policies are so important that when they are removed or changed, the resulting effects dominate the biomass market. Other policies affecting biofuels have minimal impact across sectors. In an effort to isolate the most significant or potentially potent secondary interactions we focus on three key policies—the RFS, the RPS, and the CRP—representing the transportation, electricity, and agriculture sectors, respectively.

A Framework for Critical Analysis

Given the complexity of the policy landscape surrounding the biofuels industry, we focus on three primary policies with the greatest potential for cross-sectoral (as opposed to economy-wide or intrasectoral) effects. Representing each of these three main sectors appropriately is not a straightforward task. A scenario approach is valuable since it gives a complete picture of the chosen policy combinations. Unfortunately, as more policies are considered, the number of scenarios quickly multiplies. In order to gain the best understanding of cross-sectoral interactions, we focus on one policy or type of policy from each of the three major sectors.

The RFS was selected for the transportation sector because it has the potential to be the driving force in ethanol demand for the next 15 years. The RPS was chosen for the electricity sector for similar reasons, since it would be one of the main mechanisms for increasing biomass electricity generation.[24] The CRP is the policy lever used in the agriculture sector because changes in this policy have the ability to affect 32 million acres of land and therefore dramatically change where, what type, and how much biomass is planted across the country.

In the following subsections, we evaluate these three policies jointly in eight separate scenarios. Figure 2 shows the scenarios and policy combinations in a decision tree format to illustrate the major interactions. Generally, each policy lever is evaluated for two cases: "on" or "off." "On" refers to a policy implementation case, where the existing policy landscape is changed through the enactment or enforcement of specific provisions. For example, this policy case would include either the passing of a national RPS or a major change to the CRP. The policies are placed in a rough order of importance based on the size of an effect they could have on the other sectors. To this end, we examine the RFS first since it can fundamentally change how biomass is consumed in the United States and because its effects on demand are relatively predictable based on mandated annual increases. Second, we consider scenarios that combine RPS policy changes, which do not necessarily affect biomass demand to the same extent as RFSs, since electricity generators have a choice of renewable fuels to meet the standard. Third, we consider changes to the CRP, layered on top of the RFS and RPS cases. The CRP is evaluated last not because it is least important, but because its effects are mostly on the supply side, and in and of itself it may not significantly change biomass production.

Underlying each of the chosen policies are several assumptions about how they will function individually and in combination. Many policies are difficult to evaluate since they either are not yet national laws or their implementation has yet to be determined. For others, the chosen policy depends on the progress of technological innovation. These uncertainties make even qualitative policy analysis difficult. In order to make this policy analysis as clear and generally useful as possible, we outline a number of key assumptions for each policy below.

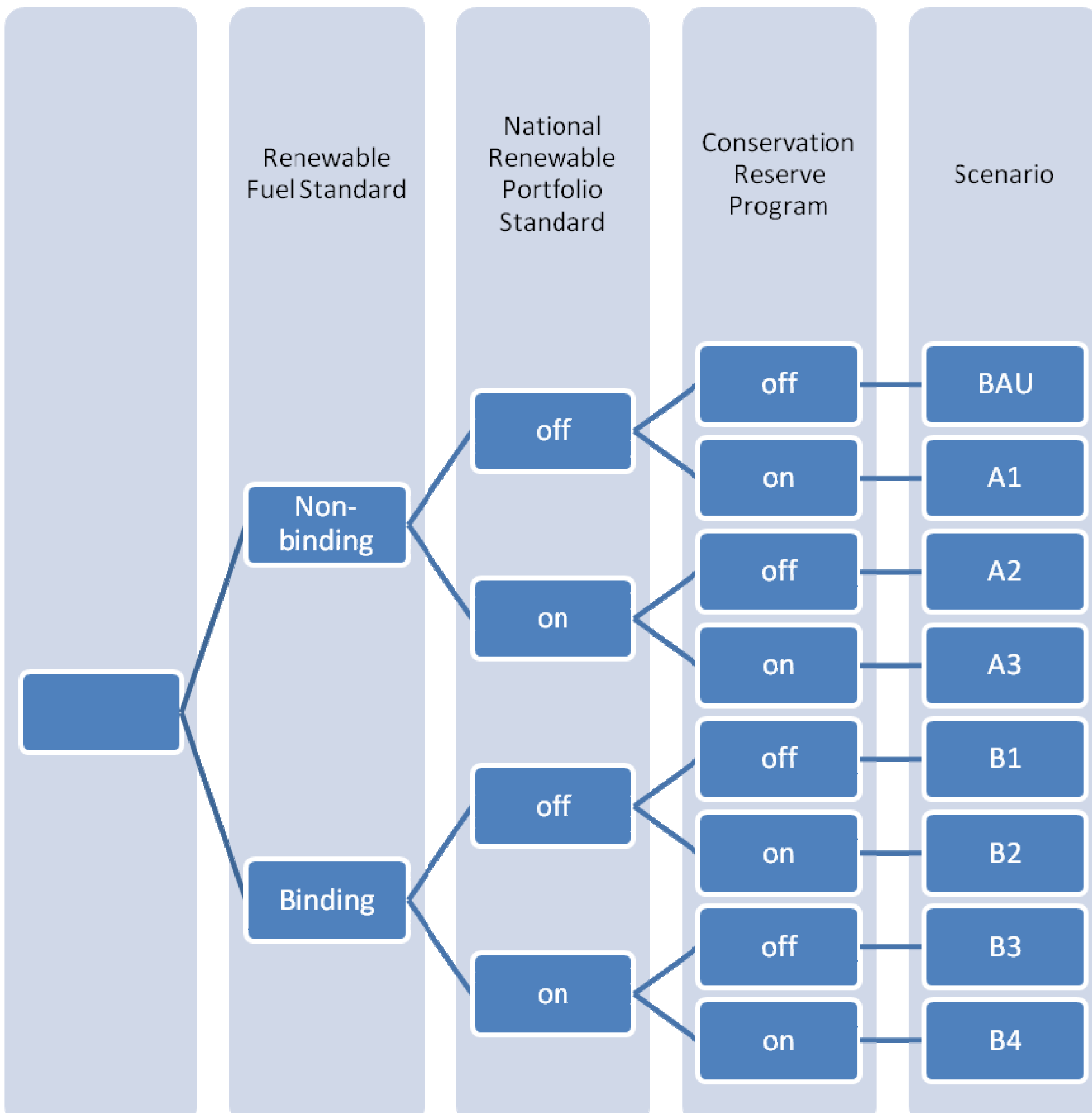
RFS

There is significant uncertainty surrounding the cellulosic ethanol components of the RFS, particularly as it concerns the process of refining cellulosic ethanol. Currently, technology exists to turn cellulose into ethanol; however, costs remain high and it is unknown if and to what

[24] "Federal RPS provisions are included in Senate Bill S. 1419 and House Bill H.R. 2950, both titled The Renewable Fuels, Consumer Protection, and Energy Efficiency Act of 2007, placed on the calendar in the Senate by Senator Reid in May 2007 and introduced in the House by Representative Wilson in June 2007. Similar proposals have been developed by Senator Bingaman, Representative Udall, and others" (Vajjhala, Paul et al. 2008).

extent they might decrease in the near future. The first cellulosic ethanol requirement under the RFS is 0.1 billion gallons by 2010, but this requirement increases rapidly after 2014, and it is unclear if the technology will be commercially viable by that point (Energy Information Administration 2008a).

Figure 2. Decision Tree Showing Scenarios and Policy Interactions



In order to account for variability in technological progress, we evaluate two possible RFS cases. In the on or binding case, commercial cellulosic technology is deployed sufficiently early to produce the mandated amount of ethanol and continues to expand to meet the RFS mandates in all future years. In the off or nonbinding case, cellulosic technology does not progress fast enough; the RFS mandates are not met and are considered completely repealed.

These two cases do not represent what would most likely happen, but instead they provide a contrast between a world with a RFS and a world without. If cellulosic technology were not commercially viable, it is most likely that waivers built into the original legislation would allow the Environmental Protection Agency (EPA) Administrator to lower the mandated levels (Energy Information Administration 2008a).[25] This intermediate case is not considered since its outcomes are likely to be similar to what happens in the binding case, just at lower levels of cellulosic ethanol production.

In our secondary interactions scenarios, we assume that RFS mandates for cellulosic ethanol are either binding or nonbinding but that the corn ethanol mandate remains in place in every scenario. We make this assumption because corn ethanol is a known quantity and meeting the 15-billion-gallon mandate is likely. Estimates of refinery capacity place current production at 10.5 billion gallons with 13 billion gallons estimated by early 2009, if not sooner (USDA Agricultural Marketing Service 2007). There is also enough corn currently in production to fuel these plants. The other fuel requirements under the RFS, however, are not as certain as the corn ethanol mandate. The biodiesel mandate of one billion gallons by 2012 is not thought to have as significant an impact as the cellulosic requirements and hence is not considered here. The additional five billion gallons of advanced biofuels is also not considered since it is relatively uncertain what form biofuels could take to satisfy this mandate.

RPS

As outlined in the primary policy objectives sections, RPSs are in force in 29 states in the United States. Although there is currently no national RPS, there have been multiple proposals for a federal standard ranging from 10–20 percent of national renewable electricity generation (Vajjhala, Paul et al. 2008). Based on existing state mandates and past proposals for a national

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[25] The 2008 Annual Energy Outlook projects that only 32.5 billion of the 36 billion gallons of biofuels required by RFS will be produced in 2022 in the reference case. This lower level will be acceptable under the mandate provisions in EISA2007 (Energy Information Administration 2008a).

RPS, in this analysis we assume that the on case corresponds to a substantially greater percentage of renewable electricity demanded nationally than under a BAU case consisting of a patchwork of state activity. The off case then corresponds to a BAU projection for renewable electricity.

Currently, there are three methods of biomass electricity generation, direct-combustion, co-firing with coal, and biomass gasification. Direct-combustion, generally fueled by forest residues in the industrial sector, comprises the vast majority of present biomass generated power. This technique, however, faces physicalefficiency limits (20 percent), and does not offer significant opportunities for expansion. In contrast, co-firing is widely viewed as the most cost-effective method for biomass electricity generation. Biomass can replace up to 15 percent of coal (on a heat-input basis) and can reach efficiencies of up to 33 percent. Biomass gasification, where biomass is converted to a synthetic gas which is then used for electricity generation, potentially could provide even higher efficiencies (greater than 40 percent). While gasification technology exists, it is not yet cost effective for widespread commercialization (Aabakken 2006).

In this analysis, we only consider co-firing with coal and biomass gasification due to the inefficiencies of direct-combustion. For the purposes of further simplification, this paper does not differentiate between the co-firing and gasification. We assume that dedicated biomass facilities can be built, albeit at high costs, when demand is sufficiently high.[26] All biomass electricity generation facilities are assumed to use forestry residues, urban wood waste, agricultural residues, and energy crops as raw fuels. Since cellulosic ethanol in the transportation sector is assumed to use only agricultural residues and energy crops, the electricity sector has exclusive access to the remaining categories of fuel, irrespective of the generation technology.

In cases with a RPS but no RFS, the electricity sector is not expected to face competing demand for biomass. This means that electricity generators will be the only buyers of dedicated biomass. On one hand, this might discourage farmers from making the switch from growing food to energy crops, but on the other it could keep the cost of raw biomass down. Ultimately, without the RFS to generate competing demand, more biomass electricity generation is likely to be built.

CRP

The agriculture sector can be difficult to analyze since there are multiple programs that shape which crops are farmed in different areas of the United States. We choose the CRP for

[26] This alternatively can be thought of as having coal plants first switch to co-fire with biomass and then having dedicated biomass facilities coming online later as technology develops further.

analysis here because of 1) the amount of land that falls under its jurisdiction, 2) the recent calls for changes in the program, and 3) its ability to change the supply of biomass. In this analysis, we consider two ways that future CRP policy could unfold. The first is that farmers would be allowed to plant biomass crops for harvest on CRP land. This would give farmers the ability to collect CRP rents and also make money from the sale of biomass products. The 2002 Farm Bill gave the Secretary of Agriculture the power to allow biomass production on CRP lands, but this authority has yet to be used (Schnepf 2007b).[27] The second change in CRP policy would allow farmers to withdraw their land without penalty. This would open the 32 million acres that are currently unavailable for 10 to 15 years to immediate planting and production.

Like the RFS and RPS, the CRP is considered to be in one of two states, on or off. When the policy is off, it is assumed to exist solely in its current state, with no changes made in the legislation. When the CRP is on, one of the two policy changes discussed above is in place. While they represent different changes in the legislation, the end result of both is that there is more land available for biomass production. For this reason, both policy changes are considered in the CRP policy on case.[28] At the general level of analysis here, drawing a distinction between these two policy levers is unlikely to make a difference; therefore, they are not addressed separately. However, it is important to note that in scenarios with high biomass demand, the difference between removing penalties and allowing biomass production can have significant effects.

An Outline of Interactions

The following section outlines the potential secondary interaction effects of the three policies and related assumptions described above. Due to the ability of the RFS to change the biofuels market, interactions are first discussed where the RFS is nonbinding. The baseline scenario, or BAU case, is described first; it outlines what might happen if no biomass policy is enforced or created. Policies are then added to highlight how the biomass industry changes as different policy levers are turned on and off in combination. Accordingly, as more policies are turned on, more interactions are found and require a more detailed analysis. The following set of subsections describes all binding RFS cases considered in combination with RPS and CRP policy changes.

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[27] Use of CRP lands, however, has been allowed for harvesting hay and livestock grazing (Schnepf 2007b).

[28] “On” and “off” are used as terms to describe if the policy is enforced or changed compared to current policy.

Nonbinding RFS Cases

BAU Case

The BAU case deals with what happens if there are no binding rules for current legislation in any sector and no additional laws are passed. This is what might be expected to happen if the RFS under EISA2007 never enforces penalties for nonattainment. Without binding RFS cellulosic mandates, corn ethanol would reach the 15 million-gallon mark by 2015, and it is likely that no further ethanol expansion would be seen. Future market forces may induce refiners to blend more ethanol into gasoline, but this would be contingent on ethanol serving as a direct substitute for gasoline on a price basis. Some limited cellulosic ethanol faculties would be built with current government assistance. If the price for cellulosic ethanol is lowered sufficiently due to technological innovation, it is possible that future ethanol production could come from new cellulosic biomass resources.

Biomass would also be used for electricity generation in the BAU case, but to a much lesser extent than if a national RPS were passed. State-level standards would probably drive most of the increases in biomass generation. Reference case projections for a 15 percent national RPS show that biomass generation will increase from 38 billion kWh to 79 billion kWh by 2015 and 102 billion kWh by 2030 (Energy Information Administration 2007b).[29] The BAU level is expected to be only one third of what is projected under a 15 percent RPS.

The BAU case also does not have any changes in government land-use programs. The CRP is assumed to remain unchanged. Farmers cannot withdraw their lands without penalty, nor are they allowed to produce biomass on their lands. Enrollment in the CRP is held constant at the 32 million acres of land currently allowed under the 2008 Farm Bill.

Scenario A1—Nonbinding RFS, No RPS, and Open CRP

Scenario A1 is very similar to the BAU case. The only difference here is that CRP policy is changed to open lands to biomass production. Although this change allows for far greater biomass production, we expect that this policy change will not have a significant effect on the biomass industry, since neither the electricity nor the cellulosic ethanol industry will demand substantial amounts of biomass. If the penalties associated with withdrawing land from the CRP program are removed, some farmers may move this land into production. The magnitude of this

[29] This is the reference case taken from the EIA 15 percent RPS report (Energy Information Administration 2007b).

change, however, is unlikely to be large without corresponding changes in demand for different types of biomass.

Scenario A2—Nonbinding RFS, National RPS, and Existing CRP

Scenario A2 captures what would happen if a national RPS were passed, but the RFS was nonbinding and the CRP stayed in its current form. Biomass demand would be governed by how the RPS is structured. Since a RPS does not drive biomass demand exclusively, demand will most likely be governed by the magnitude of the RPS, the ability of carbon-intensive utilities to trade renewable energy credits, and the price of biomass from the agriculture sector.

Considering that the electricity sector has many choices for how to fulfill a RPS, the interaction between supply and demand will be more muted then under the RFS. It is difficult to predict what would happen here, but the passage of a national RPS could create interesting regional biomass supply-and-demand relationships, where both farmers and electricity providers are partially locked into biomass purchase agreements due to transportation constraints on raw biomass. Corn stover would also be available for use by the electricity industry since the ethanol industry would not be competing for it. Access to the entire corn stover market could encourage more dedicated biomass electricity generation facilities to be built in the corn belt.

Scenario A3—Nonbinding RFS, National RPS, and Open CRP

Scenario A3 is similar to A2, except that CRP policy is changed to allow biomass production. Demand will still likely be dominated by the electricity sector through the RPS, but suppliers in this case will have access to CRP lands. Farmers will now have more land on which to produce biomass crops, meaning that they could potentially provide biomass at lower costs. CRP land distribution will also have an effect on where and how biomass is supplied and how the electricity industry chooses to satisfy its RPS requirements. States with a lot of suitable CRP land could use more biomass in their renewable electricity generation portfolios.

Without more detailed quantitative modeling, it is difficult to predict what the price for biomass would be and how changing CRP policy might influence it. Different biomass prices under scenario A2 and A1 could, however, create different outcomes for biomass use in the electricity industry. Since the electricity sector is sensitive to biomass prices relative to the price of other renewable generation under a RPS, the potential reduction in biomass price from modifying the CRP could result in more biomass electricity generation in the near term.

Binding RFS Scenarios

Making RFS mandates binding completely changes how the biomass industry functions. RFS mandates require a large amount of biomass for ethanol production, and do so with yearly increases (Figure 1). The increasing stringency of this mandate is clearly outlined, and farmers could readily anticipate increasing biomass demand and prepare accordingly. Scenarios B1 through B4 all include a binding RFS mandate that is assumed to be met regardless of the price of biomass or competing demands.

Scenario B1—Binding RFS, No RPS, and Existing CRP

Scenario B1 is the base case for binding RFS mandates. No other policy levers are turned on, and the effects of a RFS are viewed in isolation on the biomass market. Without nationwide competing demand from the electricity sector, cellulosic ethanol can take advantage of the cheapest biomass resources, wherever they might be. Biomass production is completely ethanol-dominated in this scenario. Corn ethanol will first be produced until the 15-billion-gallon mandate is met. Biomass demand will then increase based on incremental RFS requirements. Since the electricity sector is not using biomass, these mandated increases are the only source of demand through 2022. Farmers must meet this demand without access to CRP lands. Some demand could be met through corn stover, but this is unlikely to be an adequate source of supply. Dedicated biomass crops will need to be grown to generate additional supply, but it is unclear if these crops would displace traditional crops or in what region of the country they will be grown.

Scenario B2—Binding RFS, No RPS, and Open CRP

Scenario B2 is identical to scenario B1 except farmers now have the ability to take advantage of favorable CRP policies. With an increased amount of land eligible for biomass production, the demand created by the RFS can be met more easily. Newly available CRP lands also shape the location of supply. Some CRP lands are higher quality and better suited for biomass production than others; those lands are likely to be the first to be dedicated to biomass production. It is difficult to say if dedicated biomass grown on CRP lands or corn stover would be the first to be used. In fact, both could be used simultaneously. Farmers would probably take into account where cellulosic refineries would locate and plant crops accordingly.

There is a potentially interesting side effect of this case if the prices of biomass and the cellulosic production technology costs drop sufficiently. Ethanol companies may choose to satisfy corn ethanol credits by using cellulosic ethanol. Cellulosic ethanol generates 2.5 credits to every credit for corn ethanol, hence a quantity of corn ethanol could be displaced by a smaller total quantity of cellulosic ethanol (Yacobucci 2007).

Scenario B3—Binding RFS, National RPS, and Existing CRP

Scenario B3 describes a world with a high demand for biomass but without CRP land to help meet that demand. Both the RFS and the RPS will compete for biomass and the land to produce it in ways that could have far-reaching effects across all three sectors. The interaction between the electricity and transportation sectors will change how the ethanol industry develops. The cellulosic ethanol industry will be governed by the strict mandates under the RFS and will use a large and increasing amount of biomass to meet this standard. The electricity sector, on the other hand, will have more flexibility in its use of biomass due to the various choices of renewable sources permitted under any RPS. This difference in need for biomass will shape how both sectors develop and use biofuels.

The first cellulosic ethanol requirements begin in 2010, and refineries will need to find a source of biomass within two years. The first available source, without any crop conversion, is the collection of corn stover in corn-producing regions. The electricity industry would not necessarily take advantage of this resource first, but it depends on how the RPS is structured.

At current levels of agricultural production, corn stover does not exist in sufficient quantities to supply significant biomass to meet cellulosic ethanol demands. After this resource is used up, other sources of biomass will need to be developed. Increasing yields will probably play a part, but major land-use changes are also likely to occur. How these changes are made will have a significant influence on both the ethanol and electricity sectors. If a large-scale shift is made in the agriculture sector toward production of biomass, both sectors may have adequate supply at a reasonable price. This, however, may not happen, and the two industries might find themselves in direct competition for biomass resources.

A national RPS will affect each region of the country differently depending on which renewable resources are accessible. The Southeast does not have significant renewable resources outside of biomass, and this may be a primary local option in the face of a national RPS (Sissine 2007a). However, if biomass becomes too expensive, it is possible that biomass facilities will not be built at all, and other resources will be used to meet the RPS.

Under this policy case, it is also important to consider which crops get displaced for dedicated biomass production. Traditional food crops, pasturelands, and forestland are all potential candidates for conversion, if the price of biomass climbs high enough.[30] The CRP, even if unchanged, could still feel pressure from the biomass industry. Some will demand that the policy is opened up to accommodate biomass production. However, even without such changes farmers may simply decide to not reenroll their land in the program once their contracts expire. In order to keep land in the program, the CPR administrators may feel pressure to raise the compensation paid to participating farmers.

Scenario B4—Binding RFS, National RPS, and Open CRP

Scenario B4 is similar to B3, except that farmers can use CRP lands for production. Demand will be at the same high levels, but farmers will have much more land available on which to grow crops. Corn stover is still likely to be used as a primary source of biomass, followed by new biomass grown on CRP lands. This particular policy case considers two separate changes in CRP policy, one where lands are released without penalty and another where land still in the program can be used to grow biomass. The distinction is not drawn in earlier scenarios, but it can have large consequences when demand for biomass is very high. If farmers are allowed to grow biomass on their land while still collecting CRP rents, then it is likely that many will take advantage of this new opportunity to continue receiving government income while adding an additional source of profit. Program regulations, however, will most likely constrain farming techniques and will only allow approved biofuels crops to be grown.

If the CRP is changed to allow early withdrawal from the program without penalty, the results might be different since farmers will no longer receive payments. First, farmers will have the option of growing any crop, not just biomass. This decision, however, will have to take into account the opportunity cost associated with losing CRP payments. Farmers will have to earn more profit than the government payments gave them on land that they withdraw.[31] While this would most likely happen as prices for cellulose increased, the opportunity cost of CRP payments will influence how farmers are likely to respond.

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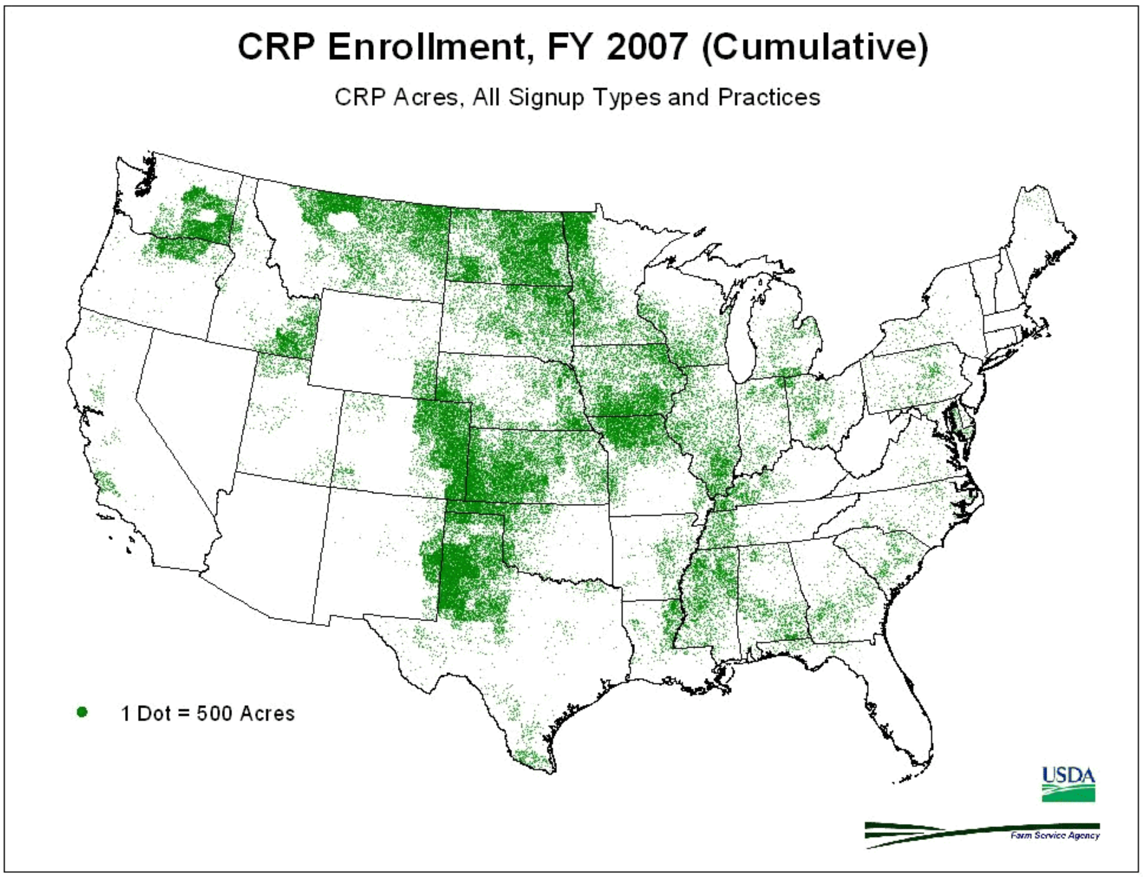
[30] It is also possible that land used to grow corn will be shifted to grow biomass (Searchinger, Heimlich et al. 2008).

[31] This works out to be an average of $51 per acre in 2007. Some land receives up to three times this amount depending on specific programs within the CRP. Lands with the lowest payments will probably be withdrawn first (Cowan 2008).

Regardless of how the policy is changed, using CRP land for biomass production will shape how supply and demand interact spatially. CRP lands are distributed across various regions in the country, but are concentrated in corn-growing states such as Iowa and Minnesota. However, there are also concentrations in the Dakotas, northern Texas, Kansas, and western Colorado (Figure 3). This wide disbursement of CRP lands means that biomass refiners and generators have multiple options for where to locate new facilities to take advantage of newly available CRP land and biomass resources.

Figure 3. Distribution of Conservation Reserve Program Lands in the United States, 2007



Source: (USDA Farm Service Agency 2007)

An Overview of the U.S. Policy Landscape

As the cases above illustrate, the biofuels policy landscape is complex. Although the secondary policy interactions described to this point capture what we think are some of the most potent and under analyzed effects of biofuels mandates, there are still many policies outside of this analysis that shape how the interactions described above could play out. These other policies are held constant in our review because they are either dominant mandates with economy-wide implications or, conversely, tangential drivers of biomass supply and demand within a single sector. This subsection provides an overview of these other policies and sets the context for our discussion of broader tertiary impacts possible through biofuels policy changes.

The Ethanol Tax Credit is a major piece of legislation that allows the price of ethanol to be competitive with petroleum-based fuels. It is likely that the corn ethanol industry would not be able to survive without the credit (Yacobucci 2007). Similarly, the Ethanol Tariff and Duty allow the U.S. ethanol industry to function without being undercut by foreign producers. Removing the tariff and duty would result in major changes to the industry and would overshadow any other policies or provisions in an analysis of crosscutting effects to the industry (Elobeid and Tokgoz 2006).

Another similar set of policies are the many crop assistance programs under the Farm Bill. These are programs integral to how the agriculture sector functions in the United States, and their modification or removal would likely result in a restructuring of the entire industry (Monke 2008). This level of transformation is outside the scope of this type of critical policy interactions analysis.

Other policies, while important to biofuels, do not change the market directly enough to be effectively analyzed. The main way that CAFE influences biofuels, for example, is through the FFV credit and the approximately seven million FFVs that have been created in response to this standard (U.S. Department of Energy EERE 2008b). This effect, while representing a significant infrastructure change, does not directly drive the supply or demand for biofuels. Instead, by putting more FFVs on the road, CAFE allows for a quicker transition from gasoline-based fuels to ethanol-based fuels. For this reason, CAFE is not discussed in the secondary policy analysis above but is addressed in our discussion of tertiary impacts on infrastructure.

Similarly, other policies that are not major drivers of biomass supply or demand work instead to magnify changes caused by the major policy drivers. The PTC is an example of an important program that makes renewable resources more competitive with fossil fuels for electricity (Sissine 2007b). However, PTC is not included in the secondary policy interaction analysis because it largely amplifies the effects of other biomass policies and does not drive biomass demand exclusively relative to other types of renewable resources. Similarly, BCAP, passed under the 2008 Farm Bill and still unfunded in the federal budget, is unlikely to reshape the biofuels industry. Instead, this program would probably work to speed the transition for some farmers from traditional crops to biomass (Yacobucci 2008b).

One final important feature of the biofuels policy landscape across the agriculture, transportation, and electricity sectors is the influence of corn stover as a biomass product. It is difficult to predict what will be the first type of biomass used without careful modeling that takes into account the relative magnitudes of the relevant effects, but some analyses have examined this question from a strictly agricultural perspective. Research has shown that growing corn and using the stover as a biomass product can be more profitable and cost-effective than growing a dedicated biomass crop (Brechbill and Tyner 2008; Vadas, Barnett et al. 2008). Much of this is related to the fact that corn is already grown in great quantity, and farmers can increase their profits by simply collecting residue that was previously left to decompose. However, policies designed to promote extensive use of this resource could have significant unintended environmental effects, as described in the next section on tertiary policy impacts.

Tertiary Policy Impacts

The effects of biofuels legislation stretch far beyond the interactions highlighted in the previous section. The use of biofuels and the policies intended to shape their production and consumption can impact the entire world. Many of these global effects have been more widely studied than domestic cross-sectoral interactions, and in this section, we briefly place our review of primary objectives and secondary interactions in this broader tertiary context. As the previous sections highlight, the potential impacts of biofuels use are vast. In an effort to stay within the scope of a policy review paper, we focus on four overarching categories of tertiary effects: food, infrastructure, environment, and economy. While these categories do not completely describe all of the impacts of biofuels, they provide a big picture of the broadest effects of biofuels use.

Food

It is impossible to talk about biofuels without discussing their potential impacts on food. Biofuels policies directly impact land-use patterns, prices for food products, and the composition of related industries. Corn ethanol has already had a significant impact on domestic and international food markets (Schnepf 2007a). In 2007, 20 percent of corn produced in the United States was used for biofuels, and this share is expected to grow in the future. Despite increasing demand, most corn grown in the United States is still used as feed for animals. Approximately 57 percent of animal feed consumed in the United States consists of corn or corn products (Schnepf 2007a). As a result, if the price of corn rises consequent to increased biofuels demand, so will the price of meat. These effects are most visible in the poultry and hog markets, which depend heavily on corn and do not have many readily available feed alternatives. There is greater flexibility in cattle feed markets, but beef is also expected to become more expensive as corn prices rise (Schnepf 2007a).

One potentially positive food impact resulting from the corn ethanol distillation process is the creation of the byproduct distiller's dried grains (DDGs). DDG is a protein-rich substance that has the potential to be used as animal feed, thereby reducing the negative impacts of higher corn prices on the feed industry. DDGs, however, also have some downsides. The ethanol distillation process uses approximately 66 percent of all original corn, limiting the amount of feed that DDGs can replace (Schnepf 2007a). According to animal nutritionists, DDGs can replace only 40 percent of food for cattle, 25 percent for dairy cattle, and 5–15 percent for poultry and hogs (Hoffman, Baker et al. 2007). These limitations mean that while DDGs are an important byproduct, they do not completely substitute for the large amounts of corn needed by the animal feed industry.

The production of cellulosic ethanol, in contrast to corn ethanol, is not expected to impact food supplies directly, but it also plays a part in the food versus fuel debate. As the price of biomass crops increases, farmers may find it advantageous to switch production away from traditional food crops to perennial grasses. These land-use changes also have the potential to affect other grain markets and consumer prices (Schnepf 2007a).

Overall, the effects of increased biomass production could have significant impacts, particularly for lower-income households. Food expenditures represent 37.3 percent of the lowest quintile's total household income (Blisard and Stewart 2007). As a result, increases in staple food prices are felt strongly. Countries that import U.S. corn are also experiencing significant impacts as a result of higher corn prices. In January 2007, for example, protests broke out across Mexico due to the almost 30 percent increase in corn tortilla prices. At present, it is unclear how such changes in corn prices could affect international markets more broadly or in the longer term. However, as the world's largest grower and exporter of corn, changes to U.S. agriculture by the ethanol industry will certainly have global impacts (Schnepf 2007a).

Infrastructure

A second major area where biofuels policies are likely to have large-scale effects is new infrastructure development. Biofuels policies are closely linked with infrastructure change in multiple sectors including the addition of networks of pipelines, power plants, and fueling stations. One of the biggest issues surrounding biofuels expansion is whether the demand for a biofuel or the infrastructure to support and supply it comes first. Biofuels policies are important in this debate because they have the ability to influence either supply or demand, depending on which policies are used in what combination. While there are many types of infrastructure related to biofuels, we focus on three main topics in this section: production facilities, distribution networks, and consumer choices.

Production Facilities

Ethanol Refineries

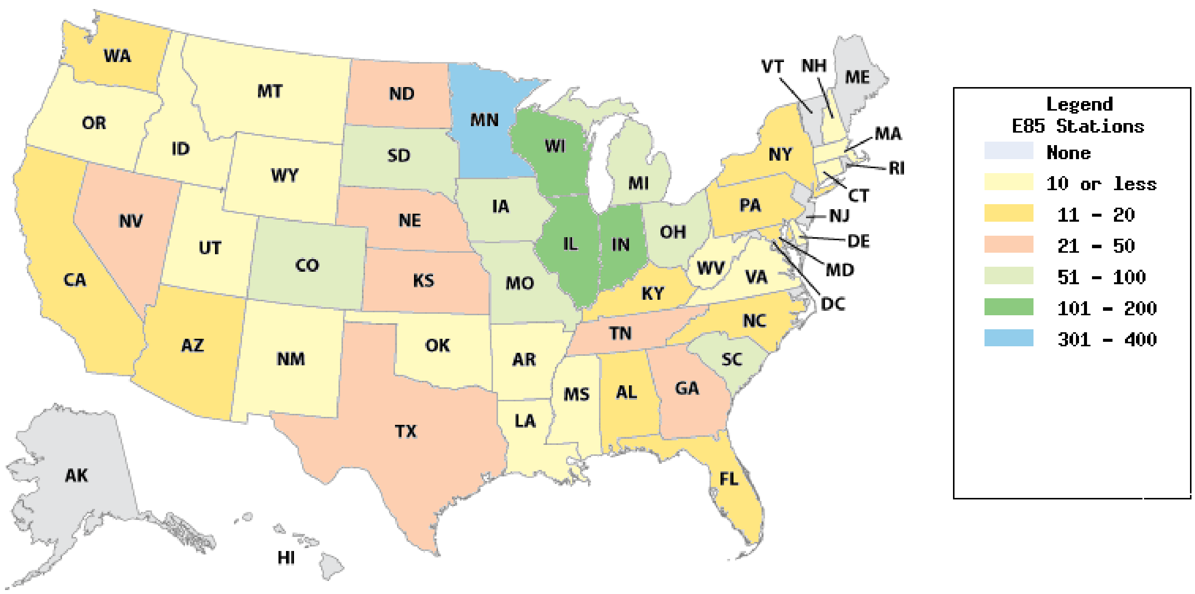
The location of new corn and cellulosic ethanol refineries under the RFS will also affect how the biofuels industry operates. Cellulosic facilities may take advantage of corn stover, a potential low-cost biomass supply, and site facilities based on its location. There are also possible financial benefits from co-locating cellulosic ethanol with corn ethanol plants to take advantage of shared purification and fermentation facilities. Cellulosic ethanol also has a byproduct that can be burned and used to power both distillation processes (Perlack, Wright et al. 2005). Co-locating cellulosic ethanol facilities with corn ethanol facilities would allow both to take advantage of existing and new distribution infrastructure (Wallace, Ibsen et al. 2005). However, because the distribution of ethanol requires its own pipeline infrastructure separate from gasoline, co-location could also put more stress on an already limited system.[32] These transmission constraints are discussed in more detail in the next section.

Another consideration is that approximately 80 percent of the nation's population (and implied ethanol demand) lives on the coasts, and it is costly to move the large amounts of ethanol as required by the RFS across the country. Even if E10 is able to reach the entire U.S. market in a cost-effective manner, excess ethanol due to the RFS mandate will have to be distributed in the form of E85. As of September 2007, there were 1,208 E85 filling stations in the United States.

[32] Corn ethanol and cellulosic ethanol are chemically identical and can be mixed and shipped together (USDA Agricultural Marketing Service 2007).

Of these, 663 were located in the major ethanol-producing states of Illinois, Indiana, Iowa, Minnesota, and Ohio (Figure 4) (U.S. Department of Energy EERE 2008a). Thus, E85 consumption could be cost-effective in states that support large-scale ethanol production facilities, but these margins are likely to be lost the further it is transported. This means that E85 could compete with gasoline in the U.S. heartland but still be prohibitively expensive in other regions of the country (Figure 5).

Figure 4. Location of E85 Filling Stations in the United States, 2007



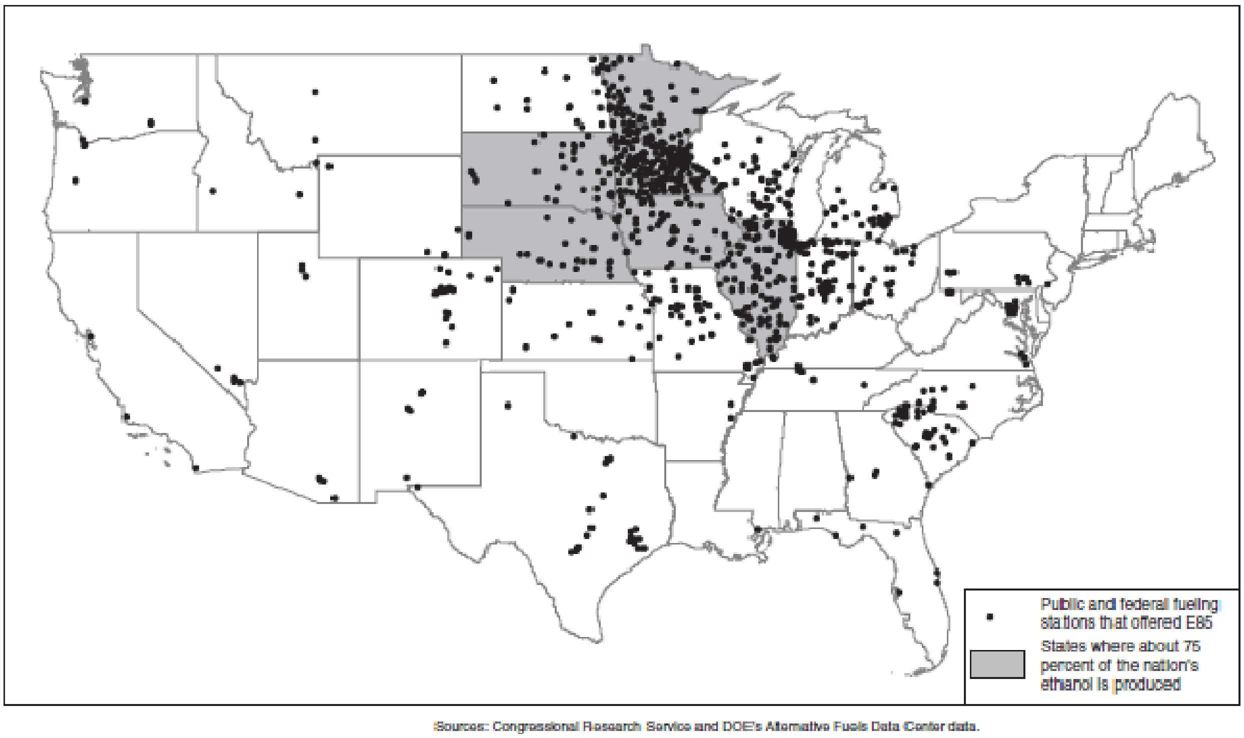
Source: (U.S. Department of Energy EERE 2008c)

Taking this into consideration, cellulosic ethanol plants could be distributed widely across the country to reduce transportation costs. This would also allow for greater distribution of new agricultural income as different parts of the country are able to profit from cellulosic ethanol production (Yacobucci 2007). Such effects, however, depend on the costs of biomass in different areas and how the industry develops over time.

Producing the required amount of cellulosic ethanol will require a large scale of refinery construction just to meet capacity demands. This increased refinery demand will most likely result in price increases for refinery construction. This has been seen with corn ethanol facilities as well, where between 2003 and 2005, refinery construction costs increased by 30 percent

(Energy Information Administration 2008a). Much of this price spike is due to the rise in prices of materials used in construction (various metals, etc.). However, it is likely that a similar cost increase will be felt across the cellulosic industry as mandates increase refinery construction (Energy Information Administration 2008a).

Figure 5. Location of Public and Federal E85 Fueling Stations, 2007



Source: (U.S. Government Accountability Office 2007a)

Power Plants

Currently, there are approximately 1,000 electricity generation facilities powered by biomass in the United States. The overwhelming majority of these (95 percent) are wood-fired facilities that use forestry residues to generate on-site power for pulp and paper industry uses.[33] Most of these are small direct-combustion facilities that use limited-residue resources, meaning

33 Two-thirds use the power and heat for on-site uses only, while others have the ability to provide power back to the grid (Aabakken 2006).

they burn wood without more efficient gasification technology. As of 2006, utility and industrial biomass represented 75 percent of non-hydroelectric renewable electricity generation with wind, solar, and geothermal generation making up the remaining 25 percent (Aabakken 2006). If biomass electricity generation were to increase, the short-term uses for biomass at large scales would most likely occur through co-firing in existing coal plants. With modification, coal plants could burn up to 15 percent biomass (on a heat-input basis). Co-firing is considered to be a mature technology, but efficiencies could be increased with technological improvements (Aabakken 2006). Future expansion of the biomass electricity generation industry will most likely be in the form of biomass gasification. This technology, while currently available, has yet to be commercialized, and it is uncertain if and when it will be deployed on a large scale (Aabakken 2006).

Distribution Networks

Biofuels supply is highly dependent on the various networks needed to move biomass from the fields where it is grown to refineries where it is distilled and then on to the final end points, such as fueling stations, used by consumers. These networks take on various forms at different phases of the supply chain. For example, ethanol can be delivered from where it is refined by truck, pipeline, or barge. Electricity is, in contrast, typically dependent on high-voltage transmission lines to move power from where it is generated to consumers. Each of these networks has its own specific characteristics that could be influenced by biofuels policy in different ways.

Ethanol Distribution

The production of ethanol is dependent on transportation networks at almost every stage of production. Transportation is considered to be the third largest expense of ethanol producers behind the cost of raw biomass and energy for the refining process (USDA Agricultural Marketing Service 2007). Biomass (corn or switchgrass) must first be transported from the farms where it is grown to a biorefinery where it will be processed. Due to the high costs of transporting raw biomass, most refineries limit the range from which they import biomass to within a 50-mile radius, based on truck transport and biomass resource costs (USDA Agricultural Marketing Service USDA 2007; Tyner 2008).[34] Once the ethanol is refined, it must be moved to

[34] Transport costs for biomass such as switchgrass are currently unknown.

where it will be used. Given ethanol's chemical properties and corrosive nature, current gasoline pipeline technology does not support the shipment of ethanol. Without major new pipeline construction or existing system modification,[35] ethanol distributors must rely on railroads, trucks, and barges, which ship 60 percent, 30 percent, and 10 percent of current ethanol stocks, respectively. All three of these methods of transport are at or near capacity, and increased ethanol production will most certainly put more strain on existing systems (USDA Agricultural Marketing Service 2007).

As RFS-mandated ethanol production increases over the next 14 years, it will be necessary to transport this fuel to consumers. The ethanol networks currently in place are inadequate to support large-scale expansion of the industry, and changes will have to be made if the extra ethanol is to be transported to new markets. The RFS, however, has the ability to shape how ethanol transportation networks form since it guarantees an increasing amount of ethanol supply and provides greater certainty to potential investors. Therefore, companies that handle ethanol transportation can increase investments in pipeline infrastructure without significant risks of facing stranded costs.[36]

Electricity Transmission

The electricity sector has its own networks for transmitting biomass. Biomass must also be transported from where it is grown to where it will be used for electricity generation. To minimize costs, biomass electricity plants frequently use biomass grown as close as possible, which typically constrains biomass facilities to areas with high amounts of biomass production. Once electricity is generated at these plants, it is then transmitted to consumers by using the transmission and distribution grid (Sissine 2007a).

Large-scale changes in where electricity is generated could present problems because the current grid is not built to carry electricity from biomass-growing regions to areas of concentrated electricity demand. Biomass, however, is thought to be one of the better renewable resources from a transmission standpoint since biomass generation is the only renewable resource, unlike wind or solar, for which the fuel itself is moveable and storable. Smaller, dedicated biomass plants can be placed closer to urban centers than other types of renewables,

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[35] A test on October 15, 2008, showed that with expensive modifications, gasoline pipelines can ship gasoline ethanol blends (Greenwire 2008).

[36] Those that own the trucks, trains, and barges along with those that manufacture the products.

and co-firing in existing coal plants allows biomass power plants to take advantage of existing infrastructure (Sissine 2007a).[37]

Similar to the role the RFS could play in encouraging greater development of the ethanol distribution infrastructure, a national RPS could have direct effects on which renewable energy technologies are built and where transmission capacity is likely to be added to support them (Vajjhala, Paul et al. 2008). The advantages biomass electricity generation has compared to other renewables mean that it could be used to satisfy large amounts of the RPS. This effect will be particularly pronounced in the South, where coal is primarily used for generation and ample land exists to grow biomass for co-firing (Sissine 2007a).

Consumer Choices

Ethanol Consumption

The RFS mandates very large amounts of ethanol to be produced from various sources. It does not, however, spell out how it must be used. Currently, conventional automobiles are only approved to only burn E10 (gasoline which is 10 percent ethanol by volume), and any higher percentage blend is thought to damage the engine's health.[38] This limitation, termed the "blend wall," presents a clear infrastructure challenge (Capehart 2008). Projections show that by 2014, the U.S. E10 market will become saturated, meaning that we will have a larger supply of ethanol than can be consumed by our conventional vehicle fleet (Energy Information Administration 2008a). Currently, the only other way for consumers to use this excess ethanol is to purchase E85 (85 percent ethanol and 15 percent gasoline) for use in FFVs. This option is dependent on the stock of FFVs, the availability of E85 fueling stations, and the relative prices of E85 and other blends.

The ability of automakers to offset standards with FFV credits has also shaped which types of FFVs are manufactured. In 2006 and 2007, 80 percent of manufactured FFVs were light trucks, which have lower CAFE standards than passenger cars; these trucks made up 50 percent

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[37] Wind from the Midwest, for example, could require massive transmission capacity compared to biomass in the southeast closer to urban centers (Sissine 2007a).

[38] Some people believe that use of E20 would be allowable. Minnesota is currently in the process of requesting a waiver to allow the production and distribution of E20 in the state. Most vehicle warranties, however, do not cover the use of more than 10 percent ethanol blends (U.S. Government Accountability Office 2007a).

of the new car market in those years. Consumers who might want to purchase a FFV thus are not presented with many vehicle size options (U.S. Government Accountability Office 2007c).

While CAFE has wide-reaching effects across the auto industry, its main impact on biofuels is the FFV credit and the millions of FFVs it prompts automakers to build. Even though most current FFVs run on conventional gasoline, they easily can shift over to E85 (U.S. Government Accountability Office 2007b).[39] If the E10 market becomes saturated by 2014 as predicted, then these vehicles could help smooth the wider transition to E85. Regardless of the intentions of the FFV credit, its ultimate consequence is that our vehicle fleet will be more prepared to switch to E85.

Electricity Consumption

While most increases in renewable energy production are policy and supply driven, consumers also have some ability to choose how their power is generated. One such choice, generally called green pricing, allows consumers to pay a premium to purchase electricity generated from renewable sources.[40] Currently, 70 million customers have the ability to purchase renewable electricity for some or all of their electricity usage, but only 560,000 (1.8 percent participation) customers exercised this option in 2006. While only a small number of customers nationally subscribe to green pricing programs, as interest in renewable energy grows these consumer choice programs have the potential to reshape demand for renewable energy production. As of 2006, green energy programs support 1,000 MW of renewable energy nationwide (Bird and Kaiser 2007).

Power companies that sell green power to customers generally do not generate the power themselves. Instead, power companies buy 90 percent of the green power they sell to customers through purchased power or renewable energy certificates (Bird and Kaiser 2007). This allows utilities that might not have the ability to generate their own renewable energy to offset these generation costs.

Other demand-side programs exist that work to reduce overall energy demand through a variety of methods, including appliance efficiency standards, voluntary energy conservation

[39] More specifically, a 2002 DOT, EPA, and DOE study found that only 1 percent of fuel consumed by FFVs was E85. This number has mostly likely increased since then, but not by large amounts (U.S. Government Accountability Office 2007b).

[40] In 2006, this amounted to approximately a $5/month premium for residential customers (Bird and Kaiser 2007).

programs, financial incentives, and government measures. Rough estimates have shown that these programs saved up to four quadrillion Btus of energy in 2000 and that they continue to reduce overall energy demand (Gillingham, Palmer et al. 2004).

Environment

Climate Change and GHG Emissions

Potential for GHG emissions reductions are one of the driving forces behind increased use of biofuels. Biomass captures carbon from the atmosphere as it is grown that is then released when biofuels are consumed. While biofuels do represent a renewable fuel that can result in GHG reductions, the net reductions in GHGs are often much smaller when all steps in the biofuels production process are taken into account. The emissions start with the agriculture sector, where GHGs are released from various agricultural processes. The refining and transportation of biofuels also requires substantial amounts of fossil fuels with corresponding emissions. Overall, the production of biofuels has the potential to provide GHG emissions reductions, but this also depends on the type of biofuel and how it is produced (Yacobucci 2007).

The agriculture sector is responsible for 6 percent of all GHG emissions in the United States. Of those emissions, 10 percent are offset by carbon sequestered, or stored, in the soil.[41] All soil has the ability to sequester carbon, but shifting land uses, changing cultivation patterns, modified tillage practices, and erosion all work to release carbon from soil. These effects can be mitigated by using conservation tilling techniques. With reduced tillage, approximately 0.2–0.3 metric ton of carbon can be stored per acre annually.[42] Moving to a no-till method can sequester 30 percent more carbon (Johnson 2007).[43] These methods, however, are not usually used in the agriculture industry without government support, and even still there is uncertainty among potential adopters of these practices. Nevertheless, around 40 percent of total U.S. farmland uses some sort of conservation tillage practice (Johnson 2007). However, as more marginal, previously unused, land comes into production, it is likely that even with soil conservation measures, more GHGs will be released.

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[41] Soil sequesters carbon mainly through soil organic matter. The carbon enters the soil through roots, litter, harvest residues, and animal manure (Johnson 2007).

[42] Crop yields and quality are not predicted to go down under a reduced tillage system (Johnson 2007).

[43] Currently, 40 percent of the carbon sequestered in the agriculture sector is due to conservation tilling techniques (Johnson 2007).

Nitrogen-based fertilizers contribute significantly to GHG emissions—overall, emissions of N_20 from the agriculture sector account for 72 percent of total U.S. N_20 emissions.[44] Biomass crops (including corn) contribute in part to this total, largely through the use of nitrogen-based fertilizers, derived from natural gas, to increase crop yields. Depending on tillage techniques, nitrogen from fertilizer can escape into the atmosphere as a GHG. As policies are put in place to increase the amount of biofuel crops grown, land that previously sequestered carbon could be turned into land subject to intensive fertilizer application (Johnson 2007).

Although fertilizers are used in large quantities in corn production, other biomass crops do not necessarily require as much fertilizer. Switchgrass can be grown with little or no added fertilizer and hence has the potential to reduce agricultural GHG emissions. However, even with lower nitrogen fertilizer use, switchgrass could contribute to GHG emissions through land-use changes and the release of sequestered soil carbon (Yacobucci 2007).

Corn stover, a frequently discussed source of biomass in this article, also has environmental implications. One of the main reasons corn stover is left on fields following harvests is that it protects against erosion and has positive effects on soil health. Therefore, even though corn stover is often described as a waste product, it is also one of the many ways through which carbon enters the soil to be sequestered (Johnson 2007). The amount of corn stover removed, and how this is accomplished, can have large impacts on both erosion and GHG emissions. It is possible to harvest some stover while maintaining soil quality and minimizing GHGs released, but incentives must be carefully designed to motivate farmers to strike an environmentally and economically efficient balance (National Renewable Energy Laboratory 2001).

The next step in the creation of biofuels is transportation of the raw biomass to either the ethanol plant or biomass electricity generation facility. Biorefineries are usually located close to biomass supplies to minimize transportation costs, and consequently GHG emissions. The next step in the process, moving the product from the biorefinery to the consumer, is vastly different for the electricity and transportation sectors. The electricity sector relies largely on a high-voltage transmission grid infrastructure to move electricity from generators to consumers. All transmission and distribution lines experience some amount of “line losses” (electricity

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[44] Agricultural N_20 emissions increase or decrease variously with different soil management practices, fertilizer application techniques, and the production of nitrogen-fixing crops (Johnson 2007).

dissipated in the transmission process), which indirectly contribute to power generation GHG emissions (U.S. Department of Energy 2006). Ethanol, however, must be transported to where it will be used. As discussed above, ethanol cannot be shipped in existing gasoline pipelines (without extensive modification) and must be moved separately in trucks, trains, or barges. Transporting ethanol from refineries to areas of demand will result in greater GHG emissions.

The emissions from increased cultivation, fertilization, and transportation of biomass products thus directly counteract the climate benefits of using biofuels. As more biofuels are produced, more GHGs could also be released from losses in sequestration and use of nitrogen fertilizer (Johnson 2007). Policies that promote and govern the production of biofuels often have direct impacts on how GHGs might be emitted or goals for GHG reduction. For example, the CRP's 32 million acres of enrolled and undisturbed land represent a large amount of sequestered carbon. Changes in the program could have large effects on GHG emissions. If farmers were able to withdraw their lands without penalty, then previously undisturbed lands would no longer be able to sequester carbon in the same way.[45] The outcomes might be somewhat different if farmers were allowed to grow biomass crops on their lands while still receiving CRP payments. Since the CRP would still have authority over the program, the government could provide incentives for various crops planted and tillage practices. Switchgrass is expected to be a less environmentally damaging crop than corn (Yacobucci 2007) and can be combined with conservation tillage practices to maintain sequestered soil carbon (Johnson 2007). If the CRP stipulated such requirements, then it is possible that allowing biomass production on CRP lands would not result in greater GHG emissions.

The RFS is also closely linked to GHG emissions through its categorization of different types of biofuels. Each of the four categories of biofuels (corn ethanol, cellulosic ethanol, biodiesel, and advanced biofuels) has different GHG reduction levels. Under the RFS in the EISA 2007 legislation, corn ethanol must achieve a 20 percent lifecycle reduction in GHG emissions, cellulosic ethanol needs a 60 percent reduction in emissions, and the advanced biofuels category requires a 50 percent reduction (Yacobucci and Bamberger 2007). The EPA has yet to release rules that define lifecycle emissions under these categories, which makes any analysis challenging (Myers 2008).[46]

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[45] The amount of GHGs released depends on which tillage practice the farmers use and which crops they plant (Johnson 2007).

[46] Current state-level RPSs do not have specific GHG reduction goals for biomass (DSIRE 2008b).

Land and Water Use

Water is an important input to agriculture generally and biofuels production specifically. Some of the greatest environmental impacts of the agriculture sector are also most directly evident through its impacts on water quality. Agriculture is considered a significant source of nonpoint source pollution and is controlled under the Clean Water Act.[47] This important piece of legislation, first passed in 1972 and updated multiple times since, limits the amount of pollutants that farmers can release into the water supply. Agriculture contributes to nonpoint source pollution through fertilizer, pesticides, and eroded soil being carried into waterways and the water supply (Copeland 2008).

As agricultural production expands under the various biomass policies, nonpoint source pollution will likely increase. This could be caused by more land being in production, higher amounts of fertilizer being used to increase yields, and/or increased soil erosion. Opening up the CRP would also contribute as the use of previously protected marginal lands might add to the runoff. Conservation tillage techniques, however, could be used to reduce erosion (Johnson 2007). The eventual outcomes all depend on how policy changes impact land uses, how existing regulations are enforced, and how new standards are introduced and enforced.

Energy Security and Economy

Energy Security Implications

A final large-scale effect of biofuels policies is in international trade. Ethanol is often cited as a recipe to increase U.S. energy security by displacing petroleum imports. While ethanol is a domestic transportation fuel source, it does not have the ability to effectively replace all petroleum-based fuel imports. Currently, corn ethanol accounts for approximately 2 percent of U.S. fuel stocks. This comparison, done on an energy-equivalent basis, takes into account the fact that a gallon of ethanol only has 67 percent as much energy as a gallon of gasoline. All comparisons here are based on a gasoline-equivalent gallon basis. Taking energy equivalence into account, if the entire 13.2 billion bushels of U.S. 2007 corn stocks were used for ethanol

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[47] The two main categories of pollution are point source and nonpoint source. Point source pollution is regulated and anticipated pollution from discrete sources such as factories. Nonpoint source pollution is harder to anticipate and is related to rain/snow runoff, construction, mining, and agriculture. Nonpoint source pollution is estimated to account for 50 percent of the country's water pollution (Copeland 2008).

production, it would only represent 16.7 percent of that year's petroleum fuel use (Yacobucci and Bamberger 2007).

Cellulosic ethanol technology, on the other hand, has the potential to generate far larger amounts of fuel. It is difficult to say to what extent cellulosic ethanol could replace petroleum-based fuels due to the uncertainty in cellulosic refining costs. Estimates, however, have shown that it could replace between 22.7 percent and 30 percent of U.S. petroleum consumption while still meeting current food, feed, and export levels.[48] One of the main uncertainties, as discussed in the secondary policy interactions section, is cellulosic refining technology. Conversion efficiency and the price of the process will drive how the cellulosic ethanol industry develops, and they will ultimately be significant determinants of how much ethanol we can use to replace petroleum imports (Schnepf 2007a).

International Ethanol Trading

Although ethanol is currently produced in several parts of the world, Brazil is considered to be the country from which the United States could most readily import ethanol.[49] Brazil's government first started subsidizing ethanol production in 1975 to help support the sugar industry, and since then the ethanol industry has continued to grow. Over the last 30 years, the government has shaped the industry with various policy interventions, but currently the industry is thriving without significant subsidization.[50] Brazil uses most of the ethanol that it produces to replace petroleum imports. Currently, ethanol represents 39 percent of gasoline demand on an equivalent-energy basis. This number is not directly comparable to U.S. numbers due to differences in the two country's transportation sectors,[51] but it provides a sharp contrast to the U.S. ethanol industry (Yacobucci and Seelke 2007).

A major difference between Brazilian and U.S. ethanol is the source of biomass. In Brazil ethanol production is based on sugarcane instead of corn. Sugarcane is a much more efficient

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[48] The upper estimate is a 2005 USDA study that is considered to be optimistic. The lower bound was from a 2005 University of Minnesota study and includes corn ethanol in the total.

[49] Seventy percent of the world's ethanol is produced by the U.S. and Brazil. Brazil produced more than the U.S. until 2004, when the U.S. took over as the world's largest producer (Yacobucci and Seelke 2007).

[50] The one important remaining policy is a mandate that all gasoline in Brazil must contain 20–25 percent ethanol (Yacobucci and Seelke 2007).

[51] The Brazilian transportation sector is much smaller than the U.S. and there are fewer cars per person. Diesel fuel also represents almost two-thirds of Brazilian fuel, so while ethanol replaces large amounts of petroleum, it only replaces around 14 percent of total highway fuel consumption (Yacobucci and Seelke 2007).

crop to grow compared to corn, and it has been estimated that Brazilian production costs are approximately 50 percent lower than those of U.S. corn ethanol (Yacobucci 2008c). The lower costs are due to the fact that corn must be broken down into individual sugars by a costly process and sugarcane does not require this step. Sugarcane waste can also be burned as a fuel in the refining process, further reducing energy costs (Yacobucci and Schnepf 2007). These lower production costs mean that Brazil has the potential to export ethanol to the United States. This process, however, is complicated by the U.S. import tariff and duty, which eliminate the Brazilian cost advantage. One alternative channel for ethanol imports is through the CBI, as discussed in the primary policy section.[52] By shipping ethanol to Caribbean countries first, Brazil can effectively export ethanol to the U.S. duty free (Yacobucci 2008c).[53] Despite their stringency, the tariff and duty do not block all direct ethanol imports. In 2007, the United States imported roughly 200 million gallons of Brazilian ethanol even with the current trade barriers. If prices of U.S. ethanol increase in the coming years, one would expect to see increased Brazilian ethanol imports (Yacobucci 2008c).

The RFS also changes the dynamic of U.S.–Brazil relations. Besides increasing demand for ethanol, which might prompt Brazilian imports, the RFS classifies sugarcane ethanol differently from corn ethanol. Sugarcane ethanol is technically classified as an "advanced biofuel" under the legislation, and hence could be used to satisfy mandates other than corn ethanol. If the U.S. cellulosic ethanol industry is not able to produce sufficient ethanol to meet the standard due to cost or refinery constraints, it is possible that gasoline blenders will turn to Brazilian sugarcane ethanol imports. This remains to be seen, as the advanced biofuels mandates start in 2009 and do not increase significantly until 2012 (Yacobucci and Bamberger 2007).

Domestic Economic Impact

Alongside the international trade implications of biofuels, the domestic economic impacts of ethanol have recently come under serious scrutiny. While the industry has been shown to have

[52] This process requires the final step, dehydration, to be done in the Caribbean country. This extra step cuts into the potential advantages of importing Brazilian ethanol.

[53] While this process allows Brazil to avoid U.S. trade barriers, only 3 percent of the allowed 7 percent was used in 2006. There are many potential reasons why this cap was not hit. Individual countries are allocated specific allowances that they can export to the U.S. Both Costa Rica and El Salvador exceeded their allowances in 2005–2007. Other stipulations in the CBI deal put limits on ethanol that isn't made from CBI feedstocks (Yacobucci 2008c).

a positive impact on some sectors of the U.S. economy, there is significant disagreement whether it warrants the levels of subsidies and government support that it currently receives. The agriculture and ethanol refinery sectors have benefited from large increases in demand. One estimate shows that in 2005 the ethanol and related industries were responsible for $17.7 billion of GDP and 150,000 jobs. While this is an optimistic estimate (Yacobucci and Bamberger 2007), it does point to the fact that there are concentrated gains associated with the ethanol industry. Most of these gains are in rural communities, where as corn prices increase, new ethanol plants are being built and staffed (Yacobucci and Bamberger 2007).

One of the larger questions surrounding the current ethanol market is whether the benefits felt by rural communities merit the subsidies and tax credits given to the ethanol industry. This is largely a political question, not a policy question, and while many say that the government support is unwarranted, there is no efficient metric by which to judge the relative merits of the ethanol industry compared to other rural economic stimulus programs (Yacobucci and Bamberger 2007).

The RFS will continue to affect the ethanol industry as corn ethanol production increases to 15 billion gallons per year as mandated. The effects of cellulosic ethanol under a RFS, however, are not well understood because they have yet to be observed. It is likely that similar effects will be seen as large amounts of government support are poured into rural communities to promote production. Cellulosic ethanol differs from corn ethanol since it does not necessarily need to be grown in a specific geographic location (Rinehart 2006).[54] These effects, however, are yet to be determined and hence any projections are purely speculative.

Consumers who are not directly involved in the refining of biofuels will be economically linked through the use of E10 blends for transportation. The magnitude of this effect depends on the relative prices of both gasoline and ethanol. If the price of ethanol remains comparatively high, then increasing mandates for ethanol use would mostly likely drive up prices at the pump. However, if gasoline prices increase and ethanol becomes a price-competitive substitute, the RFS is unlikely to result in higher prices at the pump.[55]

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[54] Corn does not need to be grown in the corn belt, but it generally is due to the suitability of the land and rainfall.

[55] This is not a consequence of the RFS, but instead of market forces making ethanol a viable substitute.

Conclusion

Biofuels have received significant attention since they first entered U.S. government policy dialogues over 25 years ago. Previous analyses of biofuels policies and their impacts, while useful in addressing the primary objectives and tertiary impacts of a policy, miss important cross-sectoral interactions that occur within the biofuels policy landscape. This paper seeks to fill that gap by analyzing biofuels policies in three building blocks: primary policy objectives, secondary interactions, and tertiary impacts. Using these three nested levels of analysis, we take a comprehensive view of biofuels policies and previously overlooked interactions.

Upon analyzing biofuels policies across sectors, it becomes clear that examining secondary interactions is an important policy analysis step. Biofuels policy in the agriculture, transportation, and electricity sectors are all closely linked and policies that affect one sector will inevitably affect others. As more policies are enacted at various levels, the interactions between sectors become stronger, and the outcomes have the potential to move further from the primary objectives of the legislation. As our qualitative analysis shows, the effects of interactions are most pronounced when biofuels policies are enacted in all three sectors simultaneously. Competing demands from both the transportation and electricity sectors are likely to drive up the cost of biomass, change overall agricultural production and land-use patterns, and ultimately shape how biomass is produced and used in all three sectors.

Through these interactions, each of the three sectors has the ability to duplicate or negate activities in other sectors. High prices generated by the transportation sector could discourage biofuels development in the electricity sector. These same high prices could distort incentives in the agriculture sector, leading to poorly allocated biomass growth and significant changes to food prices. Secondary interactions can also ripple from supply side changes in agricultural biofuels policies. Policies prompting land-use change, such as allowing use of CRP lands, could prompt farmers to grow increasing amounts of biomass even if the infrastructure to process biomass into fuel or transport it to consumers is not yet in place.

Establishing a framework though which all of these interactions can be analyzed and then placed in the larger context is the primary goal of this paper. An analysis of this nature has yet to be conducted, and in doing so we have developed a novel approach through which to evaluate biofuels policies. The cross-sectoral framework used in this policy analysis allows us to identify the potential magnitude of interaction effects with qualitative analysis and to help frame the discussion for further quantitative analysis. The goal of growing biomass resources in the United States is very ambitious, and the associated restructuring of the economy to accommodate this new source of fuel supply and demand is too large-scale to ignore the effects of inter-sectoral interactions.

This view is also increasingly important because the current policy climate surrounding biofuels is mired in uncertainty. Biofuels policies are being rapidly enacted and updated without a full understanding of their consequences. The haste to change the biofuels industry can be problematic unless there is a complete understanding of the broader implications of such changes. It is also important to remember that any policy, once passed, can be persistent and hard to change. The ethanol import duty and tax, both immensely influential laws, remain unchanged since 1980 and have been kept alive by continuing policy extensions. Considering the various levels of policy interactions evaluated here and the effects that passing or removing any biofuels legislation can have, it is increasingly necessary to understand the effects of any modification layered on to the increasingly complex biofuels policy landscape.

The potential outcomes of policy interactions have the ability to undermine the primary objectives of the legislation. Regardless of one’s view of the relative advantages or disadvantages of biofuels production and use, multiple biofuels-related policies are already in place. Ultimately, the complexity of the biofuels landscape and the lack of attention to cross-sectoral interactions to date have lead to conflicting primary objectives and potentially suboptimal tertiary effects of biofuels development.

Only through thoughtful analysis that approaches biofuels policies as an interrelated system can some of the cross-sectoral effects of biofuels be understood. As more biofuels policies are passed, the interactions between sectors will only become more complicated, necessitating further system-wide analysis. Policymakers will need better frameworks through which to take the entire policy landscape into account in order to effectively develop the biofuels industry. This review paper takes important steps forward by reframing the biofuels discussion and laying the groundwork for integrated policy analysis.

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