The Past And Future of Biofuels a Case Study of the United States Using the Institutional Analysis and Development Framework

by

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ABSTRACT

In recent years, the world has debated the idea of biofuels as a solution to energy security, energy independence, and global climate change. However, as the biofuels movement has unfolded, crucial issues emerged regarding biofuels efficacy and efficiency. The deployment of biofuels of marginal benefit has raised questions about how countries like the USA may have found themselves so invested in a potentially failing technology. In order to better understand and evaluate these issues, this study utilizes the Ostrom Institutional Analysis and Development (IAD) framework to better evaluate these issues and analyze interacting institutions that shape US biofuel policy. The IAD framework is a model that enables one to study, conceptualize, compare, and make connections across decision arenas that would otherwise be distinct from each other. By analyzing the interactions of relevant institutions, one can see how different dynamic interests interacted to shape biofuel policy in the USA today. Conclusions from this analysis include: the IAD framework is ideal for analyzing the political and economic case for biofuels. The five action arenas identified in this thesis are sufficient to understand corn bioethanol policy. A compelling case for supporting bioethanol is not made. An international agreement to reduce GHG emissions could change the landscape for biofuels. Finally, there is little prospect for biofuels playing

a significant role in the near term without greater alignment among the action arenas.

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INTRODUCTION

1.1 The Biofuels Debate

In 2007, the US Congress took a big step toward meeting the challenge of energy security by passing the “Energy Independence and Security Act of 2007”. The Act was signed into law on December 19, 2007, and began implementation on January 1, 2008. A key provision of the Act was a major expansion of the renewable fuel standard (RFS) to 36 billion gallons a year of ethanol by 2022, with no more than 15 billion gallons coming from corn or other grains and no less than 21 billion gallons coming from cellulosic feedstock in that final year. This Act built on an equally ambitious law passed just two years earlier - the “Energy Policy Act of 2005”. It was the first to mandate a renewable fuel phase-in called the renewable fuels standard (RFS). The Energy Policy Act of 2005 also created the Cellulosic Biomass Program to encourage the production of cellulosic ethanol.

The United States is not alone in its support for biofuels. Very much in parallel to US efforts, the European Union was enacting its own directives in support of biofuels. The European Biofuels Directive of 2003 (2003/30/EC) set a target of 2% biofuels by 2005 (which was not met), and a target of 5.75% biofuels by 2010 (European Parliament 2003). This directive was extended at the European Council meeting of March 2007. The European Heads of States and Governments endorsed a binding target of securing a 20% share for renewable energy in overall EU energy consumption by 2020; and a 10% binding minimum target to be achieved by all Member States for the share of biofuels in overall EU transport petrol and diesel consumption by 2020 (European Parliament 2003). In relative terms, Brazil is even more ambitious in its goals for biofuels. The majority of Brazilian fuel is gasohol which was governmentally mandated at 23% ethanol in 2006 (Marris 2006).

Yet, even as legislation, directives, and targets were being instituted, a global controversy emerged around the entire concept of biofuels. On the one hand, a number of researchers in government, academia, research institutes, civil society, and business provided strong arguments for biofuels as a public good for the United States specifically and the world more generally. For example, biofuels could reduce dependence on foreign oil improving energy security (Mazurek 2005, Sims et al. 2006, Charles et al. 2007), and reduce greenhouse gas (GHG) emissions which is good for the environment (Charles et al. 2007, Sims et al. 2006) . Biofuels when used on degraded lands could increase wildlife habitat, amplify carbon sequestration into soils, and improve water quality (Tilman et al. 2009). Biofuels could also drive more investment in rural areas and create new markets for agricultural products. They are, therefore, good for rural development, reducing poverty and migration into cities. They could also benefit food production (Charles et al. 2007, Boddiger 2007). Additionally, biofuels are attractive because they utilize existing distribution infrastructure and supply chains (Hoogma et al 2002, Charles et al 2007). Shapouri et al. (2002) and Marris

(2006) pointed out that corn and sugar cane ethanol produces more energy than it consumes and is thereby net energy positive.

At the same time, some of the benefits of biofuels have been questioned, particularly concerning the impacts on food production as well as both direct and indirect land use change. For example, biofuel production may lead to increased deforestation, and has been linked to increased food prices (Boddiger 2007, Tilman et al. 2009). Land use change significantly decreases biodiversity (Tilman et al. 2009; Costa and Foley, 1998; Fritsche et al., 2006). Additionally, Righelato and Spracklen (2007) pointed out that land clearing causes rapid oxidation of stored carbon in vegetation and soil. This creates a large up-front emission cost that would out-weigh the avoided emissions for many years. Instead, Righelato and Spracklen (2007) encouraged reforestation of an equivalent area of land which would sequester two to nine time more carbon over 30 years than avoided emissions from biofuel use.

Still other studies indicated that water competition could be exacerbated with biofuel production, as both the developed and developing world frequently experience intense competition for water between the domestic, industrial, and agricultural sectors (Boddiger 2007). Opponents of first generation biofuels argue that when one considers all inputs during stages of production, transportation and processing, biofuels are not carbon neutral (Anderson and Fergusson 2006) or energy positive (Pimentel 1991, 2003, Patzek and Pimentel 2005, Pimentel 2006).

The Energy Acts of 2005 and 2007 were not the first time governments enacted policies to support large-scale use of biofuel, nor the first time their actions have met with controversy. The first major step for the United States came with the passage of The Energy Tax Act of 1978 which provided for a 40 cent per gallon tax exemption for production of bioethanol for fuel (McDonald 1979). While the primary intent of the legislation was improving energy security by enhancing domestic production of an oil substitute, a secondary intent was to enhance markets for domestic farm products, especially corn. Speaking later – January 1980 - on the importance of this legislation President Carter said, *"Our overall gasohol program will spur the investments that we, together, must make for a more secure energy future. We will create new markets for our farmers. We will no longer have to throw away waste materials which can be turned into profitable essential fuels."* (Clean Fuels Development Coalition and Ethanol Across America 2003).

The Energy Tax Act of 1978 was passed during a period of extreme uncertainty in energy markets. In October 1973, Arab oil ministers cut oil production and embargoed the United States, causing a worldwide energy crisis which signaled the beginning of a fundamental shift in the geopolitics of oil. In parallel, the Organization of Oil Exporting Countries (OPEC), which was formed in 1960, began to exert real international influence (OPEC 2009). Then, in December of 1978 the Iranian Revolution shut down oil production and exports from Iran, creating the second energy crisis of the decade (Duffield 2008).

The passage of the Energy Tax Act of 1978 also coincided with concern for declining corn prices, as production soared following a period of robust international demand growth in the early 1970's that drove prices to near record levels. By 1977, farm income had once again become a problem, this time complicated by the price instability caused by greater reliance on export sales. Despite advancing exports, substantially higher grain production in the mid-1970s depressed prices. The corn price fell from $3.02 to $2.02 a bushel between 1974 and 1977. A new and domestic demand for corn was more than welcome (Bowers et al. 1984).

Under the circumstances, the biofuel components of the Energy Tax Act of 1978 were not especially controversial, but by 1982 questions that are still recognizable in the current debate began to emerge. Among the major concerns were the impacts on food costs and the possibility that ethanol production costs would never be competitive with oil derived fuels (Johnson and Hollman 1982). By 1986, concern about ethanol fuel programs lead the USDA to undertake a comprehensive study, which concluded:

- "The ethanol industry cannot survive during the period studied without massive government subsidies, given the outlook for petroleum prices."
- "Higher corn prices from additional ethanol-induced demand would increase the cost of producing beef, pork, and poultry. Consumer food

expenditures would rise by $8.6 billion, or an average of $2.29 for each additional gallon of ethanol produced."

- Possible improvements in technology through 1995 are unlikely to reduce ethanol production costs enough to significantly alter these conclusions (Gavett et al. 1986).

The USDA study was hugely controversial and much maligned especially by political figures from farming states (Johnson et al. 2000), and it seems to have had little impact on public support for biofuels which remained generally favorable. Nevertheless, the USDA study had the effect of drawing public attention to bioethanol and bringing the biofuel debate into sharper political focus. More than twenty years later, the debate continues although the details have evolved. This continuing debate of biofuels was a major motivation for this thesis research.

1.2 Objective of this Thesis Work

The main objective of my thesis research is to address the following questions based on the Institutional Analysis and Development (IAD) framework:

- Why did first generation biofuels enjoy such extensive public and political support as late as 2007 and now are met with increasing skepticism?
- There are calls coming from stakeholders to end support for first generation biofuels by governments. What is the justification for a shift in policy?

- What is the future for biofuels in the United States, and how is it related to energy sustainability?

In the course of my analysis, I will touch on developments in other parts of the world especially the European Union and its member states and Brazil as these regions have embarked on plans as ambitious in their own right as the US. Meaningful activities in other parts of the world cannot be overlooked because oil and grain markets are global as is the flow of information – national activities are linked through international markets and channels of communication.

To aid in this exploration I will set the debate into a framework developed by Ostrom and coworkers called the Institutional Analysis and Development (IAD) framework. The IAD framework is a powerful general model that can be applied quantitatively for simple games, but is also applicable in situations too complex to be approached as simple games (Ostrom 2005). In this case, the framework helps to identify participants, the roles they play, and the settings (action arenas) in which they will make decisions. It also helps to clarify linkages among action arenas and to show how limitations in knowledge and asymmetric access to information lead to tensions among participants and non-participants.

CHAPTER 2

INSTITUTIONAL ANALYSIS AND DEVELOPMENT FRAMEWORK

2.1 The IAD Framework as a Model for Biofuel Policy

The Institutional Analysis and Development Framework enables one to study and conceptualize the process of policy making at different scales. It guides the process of making comparisons, evaluations, and connections across arenas that otherwise might be seen as separate and distinct from one another. In the case of biofuels, and especially bioethanol, in the United States, one can see the conjoining and influence of substantially independent institutions, which in combination exert strong influence on biofuel policy, even though they may not have deep and direct interest in the area. By analyzing the interactions of these institutions, one can see how dynamic interests combined to shape biofuel policy in the USA today. Other commonly used models are dynamic simulations, where institutions and policy making usually are treated as exogenous variables. Institutions and their policies are represented as parameters to be set and evaluated for their impacts. Projections, such as the Energy Information Administration's Annual Energy Outlook and similar statistical and dynamic simulation models (e.g. Threshhold 21, and Aspen) require quantitative data to create projections. But a challenge exists with dynamic simulation models when adequate quantitative data in unavailable. For this study, data for the complex interactions regarding US biofuel policy making was not available. My purpose in this thesis is to show how policy making arises by using the IAD framework.

The foundational concept behind IAD is the notion that there are an underlying set of universal building blocks "that can be used to build useful theories of human behavior in a diverse range of situations in which humans interact" (Ostrom 2005). Figure 1 shows the IAD diagrammatically.

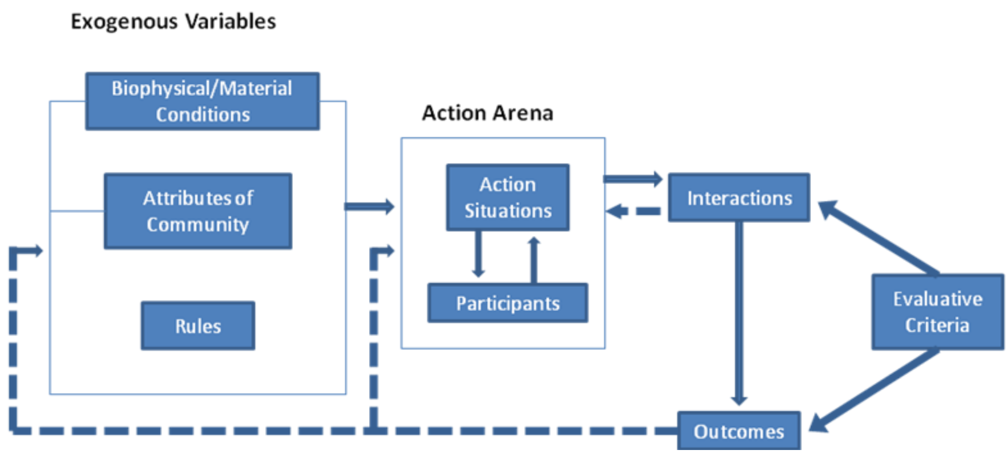


Figure 1. The institutional analysis and development framework (Ostrom 2005).

At the center of the IAD framework is the Action Arena. It is here that participants engage in social interactions that lead to outcomes which are subject to analysis. It is important to note that the evaluation criteria need not be, and rarely are, the same for all participants. Consequently, the quality of interactions and outcomes are likely judged to be very different by different parties.

The Action Arena does not exist in isolation. Exogenous variables create structure around the Action Arena. Typically, rules may be informal and largely culturally driven, but may also be very formal and codified. In either case, the rules will be known to and understood by the participants. This is not to say that the rules are always perfectly clear and perfectly obeyed – often neither is the case, but they will be sufficiently clear and understood to support an Action Arena or there would be no Arena (Ostrom 2005).

Among the rules, typically will be prescriptions that include who are legitimate participants, what positions are available, who may occupy them, and how interactions may unfold within the arena. Importantly, not all interested parties are automatically participants, nor do they necessarily have equal status. Finally, there are biophysical/material conditions, that are in the short term at least, beyond the reach of participants to change, that form the physical back drop against which participants can gauge their preferred outcomes and action strategies.

The Action Arena itself has structure as shown in Figure 2 below (Ostrom 2005). Key features of the internal structure are the participants, positions they may occupy (chairman, voters, buyers, sellers, legislator, judge etc.), and actions that are available to them. Participants may be individuals, as for example in a legislature or parliament, but they may also be organizations, institutions, countries, and businesses. For example, the international oil and grain markets have participants that are individuals, businesses, and countries all playing. These structural elements are linked to and determine the outcome set that is available within the action situation. How the linkage leads to outcomes is determined by information available to participants and the control that various participants have over the interaction and crucially the benefits each participant ascribes to potential outcomes.

In complex action situations, information is typically incomplete and held asymmetrically. As Ostrom (2005) pointed out, “When information is less than complete, the question of who knows what at what juncture becomes very important.” “When joint outcomes depend on multiple actors contributing inputs that are costly and difficult to measure, incentives exist for individuals to behave opportunistically” (Ostrom 2005). As we will see later, incomplete understanding of the exogenous biophysical and material conditions, coupled with asymmetric information in the action arena, are important contributors to the biofuel debate.

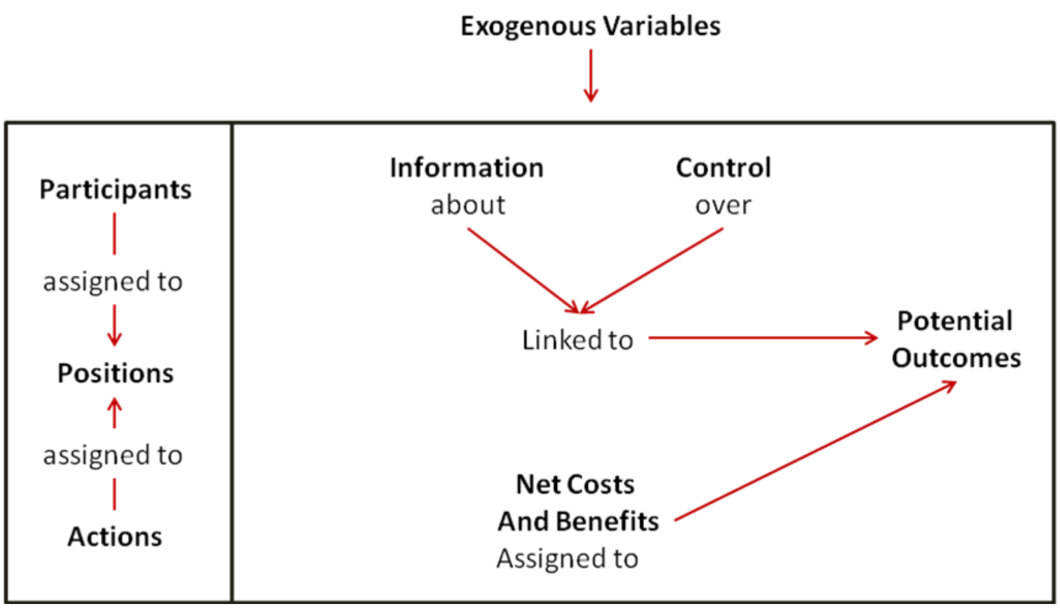


Figure 2. The internal structure of an action situation (Ostrom 2005).

In complex situations, net costs and benefits of any potential outcome are assessed differently by different participants. While it could be assumed that participants have an underlying logic for their cost benefit analysis, it should not be assumed that the analysis is complete. For example, on the cost side, all unintended consequences may not be identified or quantified.

Action situations can also exist at different hierarchical levels (Figure 3). The hierarchy recognizes that, in principle, there can be an infinite (though practically, considerably less than infinite) number of layers of overview and outcomes in structuring rules for action situations. In Figure 3, four layers are identified. As will be seen later, I will invoke just two layers to describe the social and physical dynamic of biofuels. My analysis will include three collective choice arenas – the Federal Government of the United States, the World Trade Organization and the United Nations Framework Convention on Climate Change and two operational arenas – the global oil and oil products markets and the global grain markets.

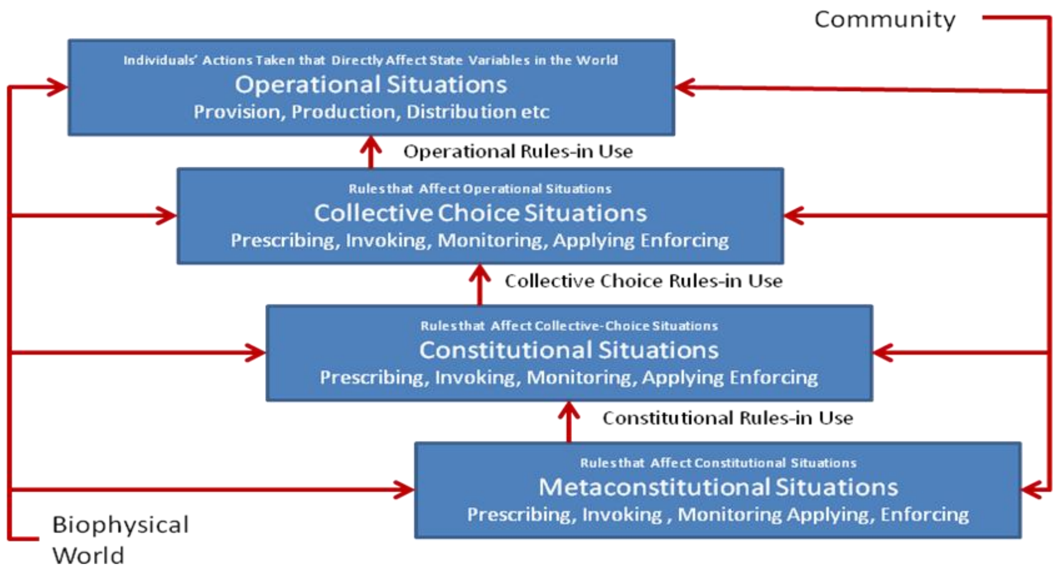


Figure 3. Levels of analysis and outcomes (Ostrom 2005).

Finally, as shown in Figure 4, action arenas can be either formal or informal. For the action arenas that I will be considering, the US Federal Government is clearly a national, formal collective choice arena, and more precisely it is an umbrella for a myriad of arenas (for example, congressional committees and regulatory agencies). The UNFCCC and WTO are international, formal collective choice arenas. The oil and grain markets have elements of both. Exchanges (NYMEX) are formally constituted with formal oversight, but it is just one of many markets that are linked in practice by largely informal mechanisms, as there is no international jurisdiction to oversee them. This difference will also feature in the biofuels debate.

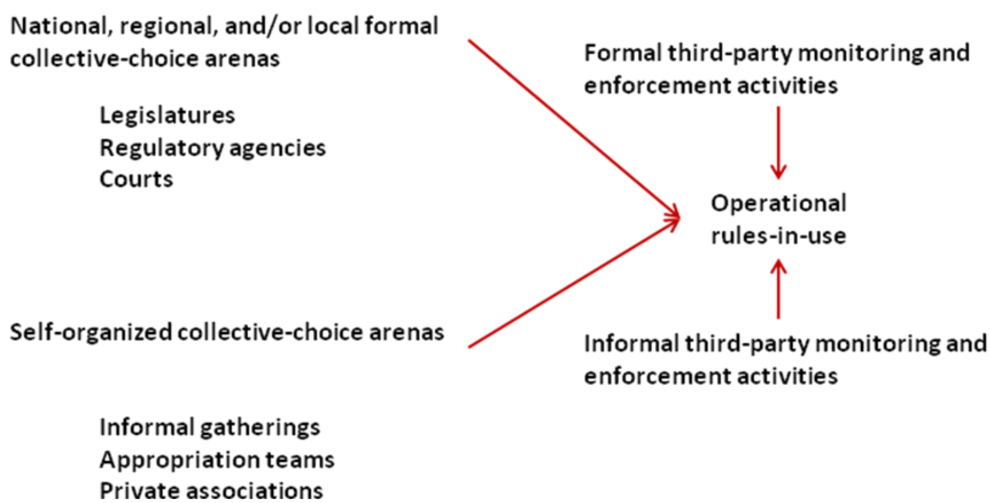


Figure 4. Relationships of formal and informal collective choice arenas (Ostrom 2005).

2.2 Action Arenas Relevant to Biofuels

Aside from sugar cane in Brazil, corn ethanol is the only other large scale biofuel in production today and likely will be the only one in the foreseeable future. As I will show in this thesis, the market dynamics for corn ethanol is largely driven by policy and legislation of the US Federal Government. The Federal Government is the most important action arena (more accurately umbrella for multiple action arenas) affecting the future of corn bioethanol. But, the Government does not act in isolation. Other action arenas also directly and indirectly influence outcomes. Ethanol as a fuel must in some sense compete with petroleum products. Thus, the dynamic of the oil markets influence outcomes regarding ethanol.   The consequences of alternative demand for corn appears as a price signal through the grain markets. Price signals affect grain ethanol competitiveness and of course food prices. The grain markets in turn are increasingly being affected by trade liberalization policies driven by the WTO. Finally, the overriding importance of climate change, as well as the emissions of greenhouse gases associated with fossil fuels, is an important driver in outcomes associated with alternative fuels. The principal driver for climate policy is the UNFCCC.

This suite of action arenas, and the dynamic interaction among them, drives the complex web of choices made by consumers and policy makers. Additionally, they are the access point to assess the historical development of biofuel policy in general, and specifically for corn ethanol in the United States. Accordingly, I have chosen the following five action arenas for this analysis:

1) The US Federal Government: The US Federal Government which can be thought of as an umbrella for a myriad of action arenas –including

congress, senate, committees, and regulatory agencies to name a few – is the primary driver of the market dynamic for corn ethanol.

2) Oil-markets: This action arena was chosen because ethanol as a fuel must compete with fuels from petroleum products, and thus the dynamic of the oil markets will influence outcomes with respect to corn ethanol. Pricing of oil products are particularly important to the competitiveness of corn ethanol and its underlying demand.

3) Grain market: Grain markets were chosen since the alternative demand for corn appears through the grain markets. The competitiveness of corn ethanol is heavily influenced by the price of corn. Additionally, grain markets are of importance because they directly influence rural income and food affordability.

4) UNFCCC: The UNFCCC was chosen as an action arena because over the last few decades, greenhouse gas emissions by fossil fuels has emerged as an international policy challenge. The potential impact of those gases on climate, has created a sense of urgency by policy makers to find alternatives to fossil fuels and to create policy to promote alternatives including biofuels. The UNFCCC is the principle arena for making climate policy.

5) WTO: This action arena was chosen because the DOHA round of negotiations will likely have a very profound impact on agriculture policy in the developed countries. Prior to the Doha round agricultural

policy remained outside of the trade discussions. However, beginning with this new round, developing countries have tied continuing trade liberalization in products and services to agriculture reform in the US and Europe. Developing countries are specifically requiring deep cuts in farm subsidies in developed countries, especially the US and Europe. Though this round of negotiations have not been completed, both Europe and the US have offered deep cuts in farm subsidies.

Conceivably one could consider others, but I argue that there are no others of comparable importance to these five. I argue this position based on two considerations. First, the US Federal Government complex of action arenas has the capacity to explore and regulate across an extraordinarily wide scope, and therefore, can in principle accommodate any new relevant developments in biofuels. Second, there are few other action arenas that have both the focus and international scope of the WTO, UNFCC, oil markets, and grain markets. One could note for example, the importance of water or land use change in the biofuel debate, but there is no national or international action arena unique to either. Currently, water and land issues must appear as exogenous variables in one or more of the arenas that I have identified, or they don’t have an easily accessible route to the biofuel decision making process.

2.2.1 US Government

The first action arena relevant to the biofuels story is the Federal Government of the United States (US Federal Government). The US Federal Government action arena is a formal collective choice arena as described in Figures 3 and 4. As such, it has extensive and formal procedural rules, tradition, and precedent to guide deliberations and decision making, as well as extensive powers to prescribe, invoke, monitor, and enforce.

Key positions in this action arena are those that can act to make law or policy (Figure 5). Included are Congress and its committees and caucuses, the President and relevant Cabinet departments, and the implementing and oversight agencies that have the power to direct. I exclude the Judicial Branch, as they have not featured large in the biofuel debate. Participants are elected in the case of the President and members of Congress. Congress selects committee heads and members from among its own membership. Cabinet heads and heads of agencies are appointed by the President and confirmed by Congress.

Among the Congressional committees of particular note are the Agriculture Committee and the Energy and Commerce Committee in the House of Representative. Those committees of relevance within the senate include the Agriculture, Nutrition and Forestry Committee and the Energy and Natural Resources Committee. These committees are responsible for drafting legislation related to energy and agriculture. The Committee Chairpersons that lead these committees play a central role in guiding legislation through the House and

Senate and occupy key positions. The Cabinet Departments, the Department of Energy and the Department of Agriculture, are also substantial positions as is the Environmental Protection Agency. As will be seen later, at various times, the participants that occupy these positions have all played major roles in shaping biofuels policy.

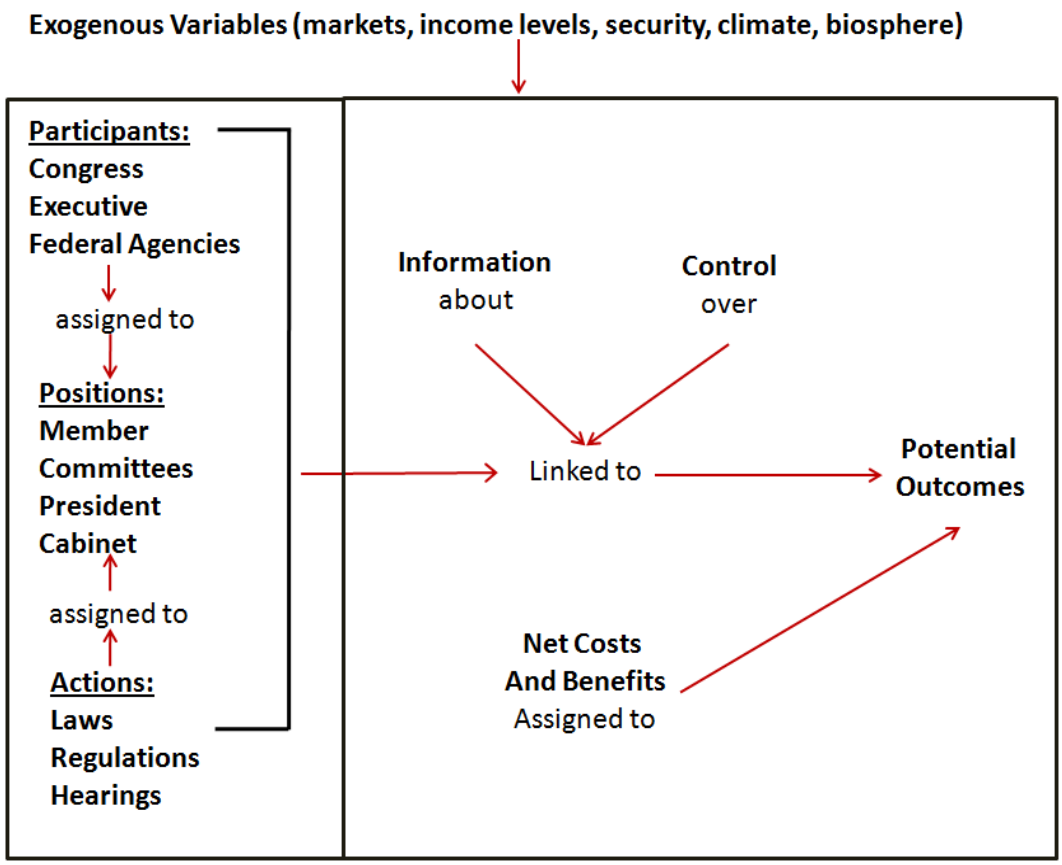


Figure 5. The internal structure of US Government action situation (Ostrom 2005).

There are many individuals and institutions that have considerable interest in the deliberations and decisions of the Federal Government (business, lobbyists, state and local governments, non-governmental organizations etc.), but they are not participants in the action arena. They form part of the biophysical and material context for the US Federal Government action arena and provide information about linkages to outcomes and in some instances, e.g. lobbyists, attempt to exert influence. But the actual positions and participants are the much smaller group above (Figure 5).

This is not to suggest that the other actors in other positions are not influential. Many are, but they exert their influence indirectly through context, and their ability to persuade actual participants. Gawande and Hoekman (2006), for example, looked at lobbying and agriculture policy in the United States. Following earlier work, which presumed that government participants trade off their personal interests with the costs that their policies impose on society, and using the Grossman-Helpman political economy model, the authors showed that the size and targeting of political campaign contributions could be understood from the equation below:

$$G = aW + C$$

where G is government policy, W is general welfare, C is campaign contribution, and a is the weight the government puts on a dollar of welfare relative to a dollar of contributions. In other words, the government is prepared to trade off welfare loss imposed on consumers by its policies for campaign contributions by those who stand to gain from those policies. Given the size of welfare (W), the weight given to a welfare dollar (a) would need to be surprisingly small for contributions (C) to have any impact at all.

Citing Freidman (2003), Gawande and Hoekman (2006) put deadweight economic losses from grain crop subsidies in 2002 at between $2 and $6 billion, while campaign contributions in the period from Farm Political Action Committees (PACs) were estimated at only about $5 to $7 million. This discrepancy in scale was explained by noting first that PAC money was highly targeted. In the 1993 – 1994 election cycle, Chairmen of the Agriculture Committees of the House and Senate were preferentially targeted, as were subcommittee chairmen. In some cases, the proportion of contributions from Agriculture PACs made up a substantial proportion of the candidate's campaign funds.

The second key factor in explaining the large discrepancy arises just as suggested by the Ostrom model. Contributions are made in advance of legislation. Powerful participants in important positions have a measure of control over the outcome (see Figure 5), but not absolute control. As Gawande and Hoekman put it, "Thus protection is for sale, but uncertainly, because lobbying contributions are made in advance of knowing the outcome." Given the uncertainties, contributions nearly 3 orders of magnitude less than the welfare cost are enough.

2.2.2 Oil and Oil Products Markets

The second action arena important for biofuels is the oil and oil products market. This action arena is not well defined nor formally organized, though elements of it, exchanges for example, are. It is a self-organized, operational arena of the type shown in Figure 4. A full description of the oil and oil products market is beyond the scope of this thesis. Nevertheless, a brief description of the essential features will aid in understanding the nature of this action arena and especially how it links to other action arenas important to biofuels. For more a extensive review of oil markets the book "*The Prize: The Epic Quest for Oil, Money and Power"* by Daniel Yergin is a good resource.

The oil market is in fact many markets ranging from private and often confidential transactions between two parties (over-the-counter) to well organized and regulated exchanges (Table 1). The different markets tend to be regional, but, because oil can and does move globally, prices equilibrate globally (Mileva and Siegfried 2007). Thus, regional markets are connected through physical movement of products between regions. This interconnectivity makes the market very flexible, but it also means that no national jurisdiction can regulate the entire market.

Table 1. International oil exchanges. Note that oil products are traded on many more exchanges around the world (Mileva and Siegfried 2007).

Exchange	**Location**	**Start Date**
New York Mercantile Exchange (NYMEX)	New York, United States	1983
International Petroleum Exchange (IPE)	London, United Kingdom	1998
Tokyo Commodity Exchange (TOCOM)	Tokyo, Japan	2001
Multi Commodity Exchange of India	Mumbai, India	2005

Within national borders, governments can and do exert great influence on the oil market by, for example, regulating exchanges (NYMEX in the US), levying taxes or imposing tariffs, controlling monopolies, establishing strategic reserves, supporting exploration within their borders, imposing environmental regulations, and funding research into alternatives (Mileva and Siegfried 2007). Few of these actions, however, extend beyond national borders. The result is an action arena with a myriad of participants ranging from private individuals trading through exchanges, to the fully integrated multinational oil companies, to the monopoly aggregate of exporting states - OPEC (Figure 6), but no single entity can exert controlling influence. In fact, as evidenced by the debate following the surge and then collapse of oil prices between 2004 and 2009, not only is no single entity able to dominate the oil market, but also it is unclear what the key factors in determining price actually are (Hamilton 2009).

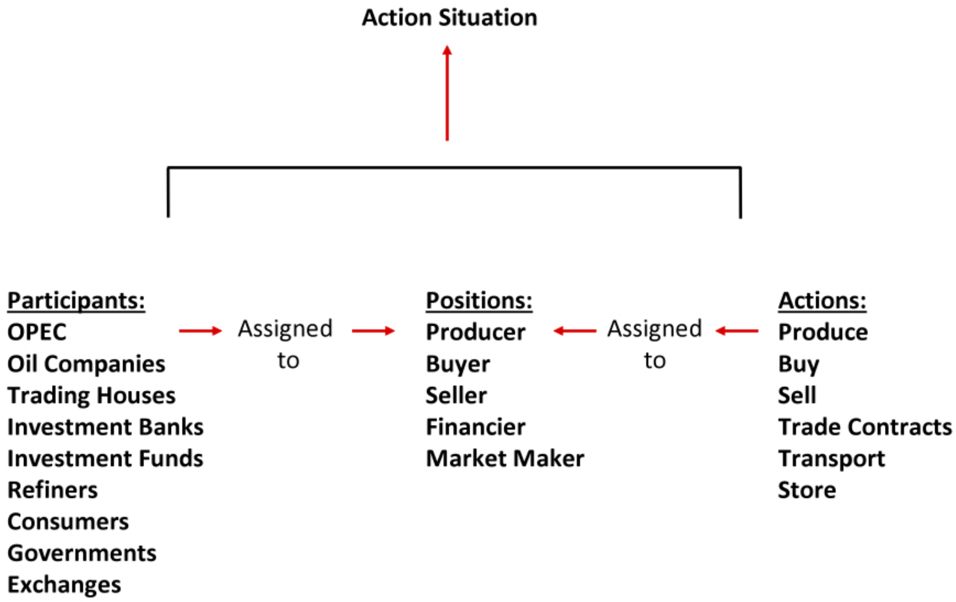


Figure 6. Participant structure of oil market action arena.

2.2.3 Grain Markets Participants and Positions

World grain markets are large, international, complex, and heavily influenced by government policy. The full grain value chain can be broken into five parts; 1) input suppliers of seeds, fertilizers, pesticides and the like, 2) producers (farmers), 3) aggregation and distribution companies 4) processors and 5) food product retailers. In addition, an array of exchanges and trading companies that support export and import of grain and facilitate steps in the chain especially aggregation and distribution. The nature of participants in this chain varies greatly, ranging from very small family farms and retail outlets to multinational agribusiness to government controlled trading firms.

The most fragmented and diverse part of the chain is the producers. The US Department of Agriculture (USDA) 2007 Farm Census counted 2,204,792 farms in the United States, a net increase of 300,000 farms from the 2002 census (USDA 2007). In order to partially offset the diminished economic power that comes from lack of concentration, producers have joined together in cooperatives. These organizations are also diverse and provide a range of services to producers including sales and marketing of farm products and procurement of materials and services for production. Typically, cooperatives are not for profit and exist only to reduce farm costs and increase farm revenues. The USDA 2007 census counted nearly 2600 cooperatives in the US, with gross business revenue of $147 billion (USDA 2007).

At the other extreme, some of the large agribusiness firms are highly integrated and participate in more than one part of the chain. The US agribusiness company Cargill for example, employs 160,000 people in 67 countries with products and services shown in Table 2 below. Archer Daniels Midland (ADM), another US based agribusiness company, has 27,000 employs and operates in 60 countries. Its products and services are also shown in Table 2. These two companies, along with Continental Grain and European counterparts, Bunge and Louis Dreyfus, play an especially important role in the international grain trade. Because they are all privately held firms, it is hard to get accurate numbers for the true scale of their operations, but Hayenga and Wisner (2000) estimate that in the late 1990s two firms, Cargill and Continental Grain, accounted for 35% of U.S. grain and oilseeds exports. Another trading company, Louis Dreyfus, exported 15% of total world grain overall.

Table 2. Cargill and Archer Daniels Midland (ADM) products and services (Cargill 2010, Archer Daniels Midland Company 2010).

Cargill	**ADM**
Animal Nutrition & Feed	Food
Commodity Trading & Processing	Feed
Industrial / BioIndustrial	Fuel
Energy & Fuels	Industrials
Farmer Services	Brands
Financial & Risk Management	Grain Merchandising
Food & Beverage	Suppliers
Foodservice	Transportation
Pharma & Personal Care	Global Services
Salt	

In the supply of seeds and agricultural inputs, other large companies are important participants. For example, Monsanto and Dow supply 45% of maize seeds to the world excluding China (ETC Group 2003). Monsanto also sold the seed for 88% of the total area planted in genetically engineered crops worldwide in 2004. Large players also populate the processing and retailing portions of the chain. Names like Nestle and Kraft in food processing and Wal-Mart and Carrefour in food retailing are substantial participants.

Another important group of participants are the State Trading Enterprises (STE). STEs are government or private enterprises that have been granted privileges by their governments, such as exclusive authority for import/export of grain and government support for operating costs. State trading is more prevalent in agriculture than in other industries, because many countries use state trading enterprises (STEs) as a means to achieve policy objectives such as domestic price support, efficiencies in agricultural marketing, and affordable food supplies for low-income populations. STEs account for significant shares of world trade in grains, dairy products, and sugar (Ackerman and Dixit 1999). STEs can be very large and account for significant shares of world trade in grains. These entities are not generally required to publish information about their activities, making data hard to get. According to Ackerman and Dixit, in 1999 the Canadian and Australian Wheat Boards were accountable together for about 24% and 38% of world exports of wheat and barley, respectively (Ackerman and Dixit 1999). The Canadian Wheat Board, which is responsible for pooling and exporting grain from the western provinces of Canada, describes itself as the largest seller of wheat and barley in the world, with operations in 70 countries.

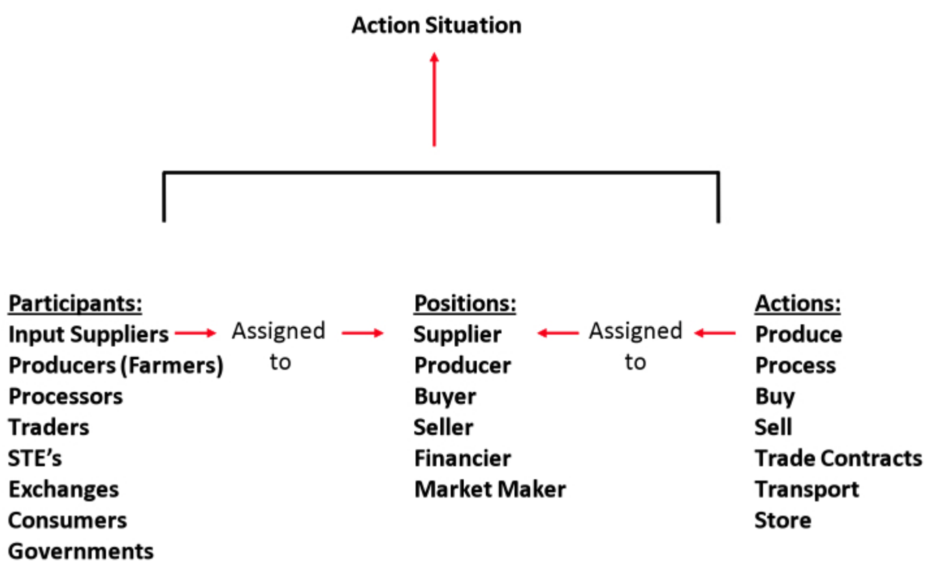


Figure 7. Participant structure of grain market action arena.

The grain market action arena (Figure 7), includes the grain exchanges. There are many exchanges around the world that trade futures contracts for grain, especially corn (maize), wheat, and soybeans. In the United States, the Chicago Board of Trade is the oldest exchange and the largest in the world for the trade of corn. Other large US exchanges include the Chicago Mercantile Exchange, the Minneapolis Grain Exchange, and the Kansas City Board of Trade.

2.2.4 UN Framework Convention on Climate Change (UNFCCC)

The fourth action arena is the UN Framework Convention on Climate Change (Figure 8). The United Nations Framework Convention on Climate Change (UNFCCC) is a treaty that arose from a United Nations Conference held in Rio de Janeiro in 1992 – The Earth Summit. The treaty is international and has as its primary goal stabilization of green house gas emission at a level that would not interfere with the climate system.

The treaty, which gained the 50 national approvals necessary to enter into force in 1994, contained no binding targets or enforcement provisions. Rather, it urged countries and especially developed countries to take appropriate voluntary actions to stabilize emissions of greenhouse gases at 1990 levels by the year 2000. It also provided for updates in the form of protocols. To date, the only protocol to be agreed to is the Kyoto Protocol, which does set out targets for Annex I countries, but again without enforcement provisions. Signatory countries were divided into three groups:

1) Annex I countries (Table 3), which are industrialized countries and which are expected to take action to reduce their emissions below

1990 levels. This group includes the current 40 Annex I countries plus the European Union.

2) Annex II countries, which are mainly the Organization for Economic Cooperation and Development (OECD) countries, which are expected to assist developing countries in reducing their emissions in addition to lowering their own.

3) Developing Countries, which have no specific obligations under the convention.

Table 3. List of Annex I countries (UNFCCC 2010b).

Australia	Austria	Belarus	Belgium
Bulgaria	Canada	Croatia	Czech Republic
Denmark	Estonia	Finland	France
Germany	Greece	Hungary	Iceland
Ireland	Italy	Japan	Latvia
Liechtenstein	Lithuania	Luxembourg	Monaco
Netherlands	New Zealand	Norway	Poland
Portugal	Romania	Russian Federation	Slovakia
Slovenia	Spain	Sweden	Switzerland
Turkey	Ukraine	United Kingdom	United States of America

The United States ratified the UNFCCC treaty and joined the convention under President George H. Bush in 1992. However, the United States under George W. Bush did not ratify the Kyoto Protocol, and the country remains outside of that agreement.

The UNFCCC is governed by the treaty and protocols agreed under it and are supported by a secretariat of the same name. The treaty provides for a number of bodies for decision making, advice, and implementation (Table 4). The role of the secretariat is to administer the activities created or implied by the treaty and protocols. An especially important function is to organize Conferences of the Parties (COP) to the Convention, Conferences of the Parties to the Kyoto Protocol (CMP), and assist the Parties (members of the UNFCCC – COP and CMP) in negotiations and implementation of agreements. The secretariat also compiles data, monitors commitments, and administers credits under the emission trading schemes. In discharging some of these responsibilities, the Secretariat is assisted by the Intergovernmental Panel on Climate Change (IPCC).

Table 4. Bodies of the framework convention (UNFCCC 2010a).

Name	Function
Conference of the Parties	Prime authority of the convention
Subsidiary Body for Scientific and Technological Advice	Counsels the COP
Subsidiary Body for Implementation	Reviews how convention is applied
Consultative Group of Experts (CGE)	Helps developing countries prepare national reports
Least Developed Country Expert Group	Advises on climate adaptation
Expert Group on Technology Transfer	Facilitates sharing of technology

COP is the ultimate decision-making body of the Convention, which meets every year to review the implementation of the Convention. Successive decisions taken by the COP make up a detailed set of rules for practical and effective implementation of the Convention. Only parties to the convention can participate in decision making. Governments nominate their respective representatives to participate and negotiate at the sessions of the Convention and the Kyoto Protocol. Representatives typically include ministers, negotiators, and those who the governments consider necessary to achieve their goals during the sessions.

Though not a part of the UNFCCC, the IPCC is an important entity in the overall climate issue because of the very important role it plays in compiling and interpreting scientific information. The IPCC does not carry out research, nor does it monitor climate. Rather, the IPCC is an intergovernmental scientific body tasked to evaluate the risk of climate change caused by human activity. The panel was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), two organizations under the United Nations.

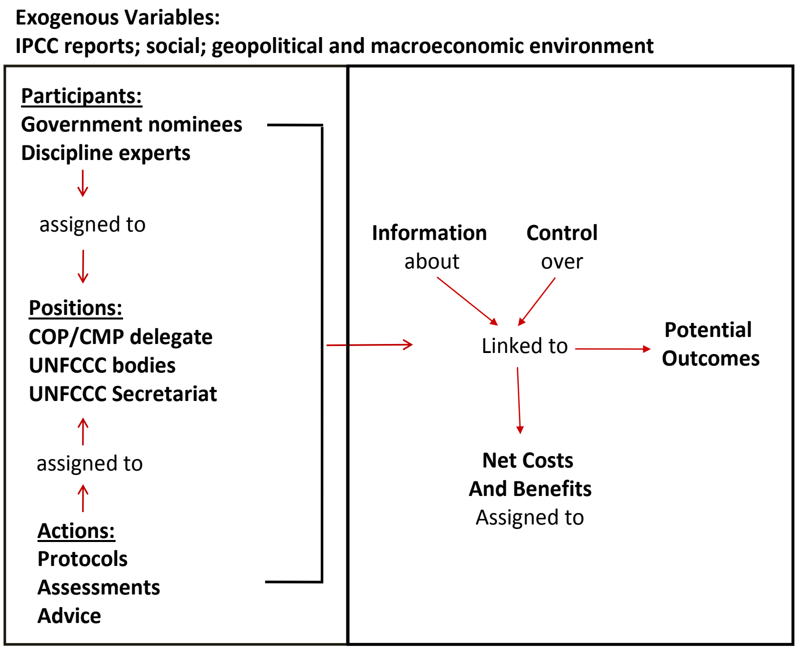


Figure 8. The internal structure of UNFCCC action situation.

Reports of the IPCC are approved by a complex process of drafting, review, debate, and consensus building as shown in Figure 9. While generally seen as authoritative, they also are often controversial both with respect to the science and the political overtones of their reports (Dahan-Dalmedico 2008). The IPCC has published four comprehensive assessment reports reviewing the latest climate science, as well as a number of reports on special topics. Because they are authoritative they form a critical part of the biophysical/material background to the UNFCCC action arena.

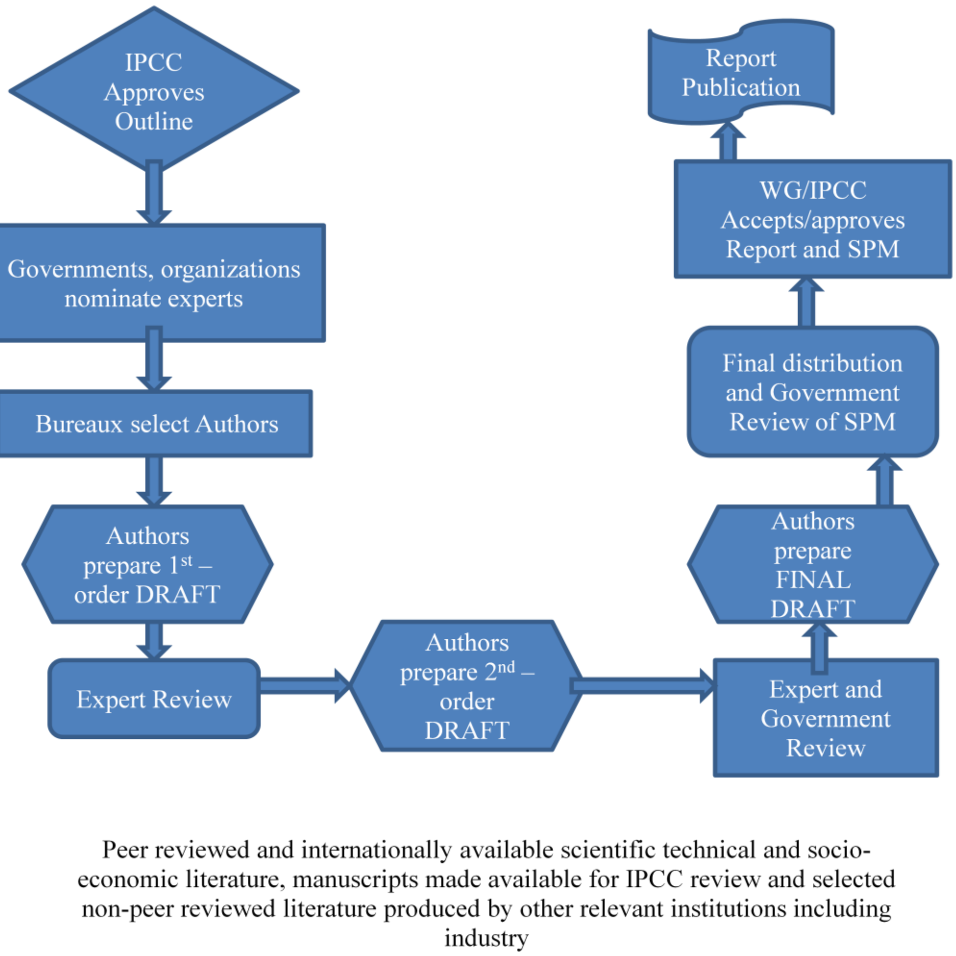


Figure 9. IPCC report process (Saundry 2008).

The IPCC is itself governed by a formal governance system. Membership in the IPCC is only open to member states of the WMO and UNEP. The IPCC Panel, the governing body, is composed of representatives appointed by governments. However, participation of delegates who have appropriate expertise but who may not have been appointed by a government is encouraged. In this case, additional experts may attend upon invitation of the Chairman and approval of the Panel. In this way international, intergovernmental, or non-governmental organizations may participate in panel discussions, task forces and working groups (IPCC 1998). Plenary sessions of the IPCC and IPCC working groups are held at the level of government representatives. Nongovernmental and intergovernmental organizations may be allowed to attend as observers subject to approval by the Panel (IPCC 2006)

2.2.5 World Trade Organization and the General Agreement on Tariffs and Trade.

The fifth and final action arena is the World Trade Organization (WTO) (Figure 10), and its predecessor organization the General Agreement on Trade and Tariffs (GATT). By their own description, the leadership of the WTO see themselves in a number of different ways. "It's an organization for liberalizing trade. It's a forum for governments to negotiate trade agreements. It's a place for them to settle trade disputes. It operates a system of trade rules" (WTO 2007). The WTO grew out of the GATT which was formed in 1947 and lasted until 1994, when it was replaced in 1995.

The World Trade Organization (WTO) does not currently have a trade regime specific to biofuels, as it does with agriculture products for example. International trade in biofuels is governed therefore, under the rules of the General Agreement on Tariffs and Trade (Selivanova 2007), which covers trade in all goods. Because it creates an international framework for trade in goods and services the WTO is important to biofuels and especially bioethanol. Bioethanol can be affected directly through rules governing its international trade but also indirectly through rules applying to agriculture and energy products.

The WTO is composed of 153 member countries and it is run by its member governments. All major decisions are made by the membership as a whole and decisions are most often made through consensus. The WTO has four layers of authority. The highest level of authority is the Ministerial conference, who may make decisions on all matters of any multilateral trade agreement. They meet at least once every two years.

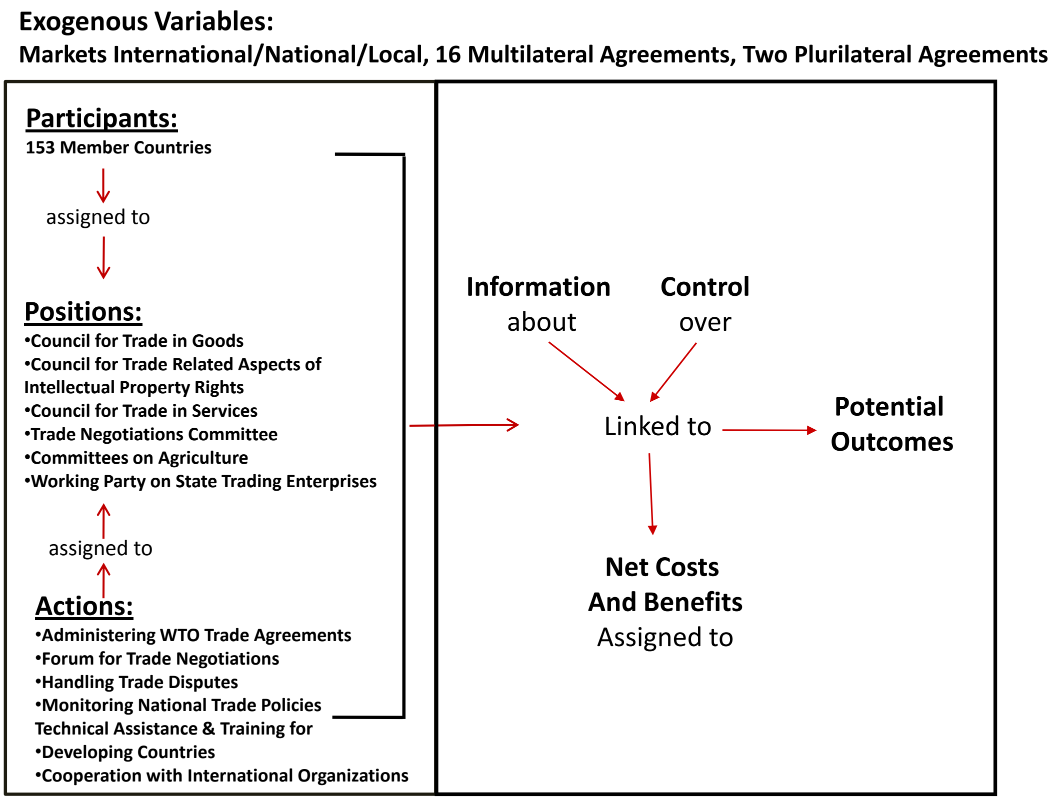


Figure 10. The internal structure of WTO action situation.

The second tier of authority is composed of the General Council, who reports to the Ministerial conference, and acts on their behalf on all WTO affairs. While technically being one General Council, this group is handled under three differing guises, the general council, the dispute settlement body, and the trade policy review body. The groups are all of the same entity but simply meet under different terms of reference. The third level of authority is composed of three further councils who report to the general council. Each council is assigned to a different broad area of trade. These three councils are the council for trade in goods, the council for trade in services, and the council for trade-related aspects of intellectual property rights. Six other bodies also report to the General Council, and focus on issues regarding trade and development, regional trading arrangements, the environment, and administrative issues. Due to their smaller scope of coverage they are referred to as "committees".

The fourth and final tier is composed of subsidiary bodies, which each of the higher level councils have. This group of higher level councils includes the Goods Council, the Services council, and the Dispute Settlement body (at the general council level). The Council for Trade in Goods' committees include subjects like agriculture, market access, trading, subsidies, and so on. The Council for trade in Services fourth tier bodies include financial services, domestic regulations, GATS Rules and specific commitments. The Dispute Settlement Body has two subsidiaries, the dispute settlement panels and the Appellate Body.

Negotiations of the WTO take place in rounds. Table 5 shows the rounds and principle themes of negotiations since the beginning of GATT. Negotiations today take place under what is known as the Doha round. This is the first round of new negotiations under the WTO. It began in 2001 and was expected to be concluded in January of 2005. That deadline was not met and negotiations continue under the Doha round.

Energy has mostly not been addressed by international agreements, and until recently, there was a common perception that GATT rules did not apply to trade in energy. This perception arose mainly because in the 1980s most energy producing countries were not parties of the GATT agreement. This is understandable, especially in the case of countries rich in energy resources, since their energy exports did not encounter market access barriers. On the other hand, becoming a contracting party to the GATT would oblige them to undertake binding commitments and to open domestic markets.

Table 5. Negotiating rounds under GATT and WTO (WTO 2007, Wikipedia 2010b).

Year	**Place/name**	**Subjects covered**	**Countries**
1947	Geneva	Tariffs	23
1949	Annecy	Tariffs	13
1951	Torquay	Tariffs	38
1956	Geneva	Tariffs	26
1960-1961	Geneva, Dillion Round	Tariffs	26
1964-1967	Geneva, Kennedy Round	Tariffs and anti-dumping measures	62
1973-1979	Geneva, Tokyo Round	Tariffs, non-tariff measures “framework” agreements	102
1986-1994	Geneva, Uraguay Round	Tariffs, non-tariff measures, rules, services, intellectual property, dispute settlement, textiles, agriculture, creation of WTO, etc	123
2001 - Present	Doha Round of WTO	19 subjects including agriculture	

As energy rich countries diversified their economies they saw more incentives to participate in trade agreements. While their energy exports did not have obstacles to reaching the export markets, their downstream products often did. Fertilizers, ammonia for example, often needed to compete in the export markets with the subsidized domestic production of importing countries. Market access problems became an increasing concern for energy-rich countries.

With accession of some major world energy and petroleum producers to the GATT and the WTO, the issues of energy trade became increasingly apparent. The US and the European Community raised energy during the Tokyo and Uruguay Rounds of multilateral negotiations. Little progress was made as the proposals met with opposition from energy-rich countries.

It is now commonly accepted that existing WTO rules do apply to energy products. The problem is, however, that these rules are not well designed to address the energy sector (Selivanova 2007). Energy and especially energy services are likely to be more prominent as the Doha round continues, but still a minor theme and substantial adjustments are not likely soon.

In contrast an important theme of the Doha round and one where much effort has been expended to extend trade rules is agriculture. Agriculture was essentially exempted from early rounds under GATT as it was given special status in the areas of import quotas and export subsidies, with only mild caveats. However, by the time of the Uruguay round in 1986, many countries believed agriculture needed to be addressed. Agreement was reached in 1994 on the

Uruguay Round, and it included a substantial trade liberalization agreement for agriculture. Among the goals for the Doha round are to improve market access for agricultural products, reduce domestic support of agriculture in the form of price-distorting subsidies and quotas, and eliminate over time export subsidies on agricultural products.

Progress on any of these goals will have direct and immediate impact on US agriculture policy, as at a minimum, the 2008 Farm Bill would not comply with the intent of the Doha Round (Murphy and Suppan 2008) .

CHAPTER 3

EVOLVING PERSPECTIVES ON THE FIRST GENERATION BIOFUELS

3.1 Introduction

Turning now to my first core question: Why did first generation biofuels enjoy such extensive public and political support as late as 2007, and now are met with increasing skepticism? Policy towards biofuels in the US, and in other parts of the world, has been evolving continuously since the 1970's, largely driven by economic factors, especially supply and demand of oil products and grains, as well as the social and political consequences of decisions associated with the five action arenas described above. Consequently, the IAD makes an effective framework for understanding factors effecting policy decisions. I will focus on four time periods that are defined by important acts passed by the US Government (Table 6). These acts both embodied the sense of public discourse around the three other action arenas and set new policy direction. The four time periods I will assess with the IAD framework are:

1) Pre-1978 which ends with the passage of the Energy Act of 1978,
2) 1978 to 1989 which ends with the passage of the clean air act amendments of 1990,
3) 1990 to 2004 which ends with the passage of the energy act of 2005
4) 2005 to the present

For each time period I will provide context by looking at the exogenous variables for each relevant action arena, then how outcomes in these arenas interacted to shape policy debate and ultimately acts of Congress.

Table 6. Periods for analysis of policy development.

Time Period	**Defining Event**
Pre 1978	National Energy Act of 1978
1978 – 1989	Clean Air Act Amendments of 1990
1990 – 2004	Energy Policy Act of 2005
2005 – Present	Continuing. Not Yet Identified

The role of the action arenas and the dynamic interplay among them has varied considerably over time. In fact, the UNFCCC wasn't even created until 1992, and did not enter into force until 1994. Additionally, agriculture policy didn't become a serious part of the WTO negotiations until the Doha round which began in 2001. In order to understand the evolution of biofuel policy, it is helpful to break the analysis into time periods. There is an element of arbitrariness about choosing time periods. In selecting the time periods, I have been guided by defining events that have substantially changed the policy environment. Not surprisingly these events have been the result of a major legislative action by the US Federal Government.

The first time period is pre 1978. In 1978, the US Federal Government passed The National Energy Act of 1978. This was a watershed piece of legislation for biofuels because it was the first time the US provided significant subsidies for the production of bioethanol. The second time period I selected is

1978 to 1989. This period ends with the passage of the Clean Air Act Amendments of 1990. Until the amendments to the Clean Air Act were passed, the principle policy driver for corn ethanol was the tax subsidy arising from The National Energy Act of 1978. With the passage of the Clean Air Act Amendments of 1990 entirely new markets began to open up for bioethanol. These new markets created a richer dynamic in the market place and in policy arenas. The third time period is 1990 -2004. This period ends with the Energy Policy Act of 2005. This act is important because this was the first time the US Federal Government mandated the use of bioethanol in reformulated gasoline, and set targets for biofuels in the transportation sector (table 11) . The final time period is 2005 – present. This period continues into the immediate future.

3.2 Pre -1978

3.2.1 Exogenous Variables

Government policy is of particular importance as agriculture is central to issues of social stability in all countries. Hayami and Godo (2004) have developed a compact framework for assessing agricultural goals that drive government policy. They identify three agricultural problems:

1) For developing countries, avoiding food shortages
2) For middle income countries, lagging farm income
3) For developed countries, farm income protection

Irrespective of the problem, the policy response tends to be substantially the same - government intervention to move prices of agricultural products, or to moderate the impact of global prices to suit the country's social needs. Quoting Hayami and Godo (2004) "political distortions in both developed and developing countries are the major determinant of food trade. In high-income countries, despite chronic oversupply of food, domestic farm production continued to be subsidized heavily, resulting in substantial burdens on consumers and taxpayers. On the other hand, in low-income countries, governments often employ agriculture-exploitation policies, further aggravating their food shortage."

The scale of these impacts is large. At the high end, Anderson et al. (2006) estimate that, by 2015, full liberalization of trade in agriculture will result in $173 billion of annual real income gain worldwide against a 2001 baseline (Anderson et al. 2006), with the benefits split roughly one third to developing countries and two thirds to developed countries. Other estimates are lower but still substantial (Table 7).

Yet trade liberalization in agriculture products has met with serious difficulty in the Doha round of the World Trade Organization (WTO) negotiations. Two frequently cited obstacles are the need for the EU to be persuaded to make bigger tariff cuts in agriculture, and the US needs to accept bigger cuts in domestic agriculture subsidies (Kernohan 2006).

Table 7. Results obtained in OECD & other studies of trade liberalization (Kernohan 2006).

Study	**Liberalization scenario**	**Global welfare gains ($billion)**		
		Agriculture	**Other**	**Total**
Ash & Tangermann (2006)	50% cut in domestic agricultural support 50% cut in applied tariffs – all sectors, all regions	26	18	44
Anderson et al. (2005)	Elimination of domestic agricultural support and trade protection in all sectors	173	105	278
Beghin et al. (2002)	Elimination of agricultural support and protection in high-income OECD countries	108	n/a	n/a
François et al. (2003)	Elimination of tariffs, all sectors, all regions	109	107	367*
Hertel & Keeney (2005)	Elimination of domestic agricultural support and tariffs – all sectors, all regions	56	28	84
OECD (2003)	Elimination of trade protection, all sectors	34	63	174**
Tobarick (2005)	Elimination of domestic agricultural support and trade protection	20	n/a	n/a
UNCTAD (2003)	50% cut in applied agricultural support and tariffs, all sectors	31	n/a	n/a
USDA (2001)	Elimination of domestic agricultural support and tariffs, all sectors	56	n/a	n/a
World Bank (2003)	Near 100% reduction in domestic agricultural support and applied tariffs	193	98	291

* Includes gains from services liberalization. ** Includes gains from trade facilitation.

The problem facing both the EU and US can be understood within the Hayami and Godo (2004) model. For the US, the problem originated in the early 1920's. According to Bowers et al. (1984), "The relative decline in the farmers' position had begun in the summer of 1920 when the United States began the transition from a debtor to a creditor Nation after World War I, resulting in a continued loss in the volume and price of exports. Thus, for a decade farmers were caught in a serious squeeze between the prices they received and the prices they had to pay before the situation became critical and a major element of the Depression." Until then, and especially in the period just after the turn of the century, farm income was relatively stable and farmers held acceptable purchasing power in relative terms. By the early 1930's their income relative to city workers was seriously eroding, leading to Agriculture Adjustment acts in 1933 (73rd Congress 1933) and 1938 (75th Congress 1938) and the introduction of the concept of parity. Parity seeks an equality of exchange relationship between agriculture and industry or between persons living on farms and persons not on farms.

In the Hayami Godo (2004) model, the US was now a category 3 country. Since that time, politicians particularly from rural areas have felt a powerful need to protect rural income. Similar events and pressures have unfolded in Europe as much of the region became category 3 as well. The challenge to policy makers in the US is made more difficult due to the market structure for agriculture products.

As pointed out by Murphy (Murphy 2008), markets are riddled with power imbalances, making the assumption of perfect competition untenable. Those assumptions include perfect information flows, no barriers to new entrants in the market, and the capacity to adjust supply smoothly and rapidly with changes in demand. Agricultural commodity markets are particularly prone to failure. Agricultural market realities include a range of imperfections:

- The ‘hour-glass’ shape of the market: many farmers sell to a handful of processors or grain traders, who then add value to the commodities to make food which is sold to many consumers.
- Slow supply and demand responses to changes in the market: while new ways to use food are constantly emerging, people do not double their meat intake if the price of beef drops by 50%. Should a drought wipe out an important part of global production, it would take 6-12 months or more to increase supply.
- Land does not easily come in and out of production: land ownership in most countries is decentralized and individual farmers cannot afford to keep land idle. Typically, a farmer’s response to either high or low prices is to increase production. This makes downward price spirals related to overproduction hard to halt.
- Land is not mobile. The textile industry can shift production from the US or Italy, to China or Bangladesh, because capital can move to buy and build the necessary factories, and labor is available everywhere. But no amount of trade liberalization can move arable land from the US or Brazil to Bangladesh.

Low prices may marginally reduce production, but, on the whole, agricultural markets do not self-adjust easily. The first land to go out of production is the marginal land with the lowest per acre yields. Farmers generally cannot afford to miss a year's crop or to absorb the cost of maintaining idle land (and storing equipment that depreciates annually). Over the past century, developed countries have experienced a simultaneous dramatic reduction in the number of people living directly from agriculture, but increased overall yields, with the amount of land in production staying relatively unchanged. Individual farmers cannot affect overall supply through their production choices because they do not grow enough to affect total supply in the market, even locally, let alone at the global level. Economic logic thus dictates that farmers maximize their production whether prices are high or low. High prices bring new producers (and, especially, new land) into production, but low prices are slow to push existing producers out, or to reduce production. The opportunity costs of exiting are high because there is no quick way back in and because most agriculture takes years to show a return.

The market structural problems are exacerbated by technological advances in agriculture that have enabled agricultural productivity to increase relative to non-farm goods and services in the US. Technological advances in bioengineering have contributed to a significant, and still lasting, productivity growth in agriculture and the trend is likely to continue. Milijkovic et al. (2008), assessed a range of reasons for the decline of relative farm income and found that increased productivity from technological improvement the most prominent factor. Interestingly, he also observed that by increasing direct payments to the farmers, government encouraged continuous overproduction, and overproduction in the sector, leads to lower market prices and returns.

In the period to 1978, US Agriculture policy was characterized by increasingly sophisticated measures to sustain farm income while avoiding catastrophic budgetary impacts. However, the 1970's were a benign period as the position of agriculture had changed profoundly from where it had been a decade before. World crop shortages and a falling dollar sharply escalated the trend toward greater export demand for American crops. Following the Soviet grain sale of 1972, grain exports nearly doubled between 1972 and 1973. Government grain stocks, which had depressed grain markets, were essentially eliminated. Even higher output by grain farmers was quickly absorbed by the market. It appeared that demand had fully caught up with supply, and that demand would continue strong for the near term.

In fact, the agricultural markets had become so favorable that policy emphasized expanded production to respond to growing worldwide demand and to hold down price increases. In March 1981, Secretary Block proposed a farm bill to reduce the role and expense of Government in agriculture and rely more on export promotion. Shortly after Congress received this proposal, each house passed a budget resolution calling for major cuts in spending, including agricultural programs.

There were clouds on the horizon, however. High farm prices increased demand for farmland that drove land values up. Greater dependence on export markets made commodities more vulnerable to price swings from economic or political events in other parts of the world. Meanwhile, continued food price inflation brought consumer demands that support for agriculture be reduced (Bowers et al. 1984).

In contrast to the relatively stable grain markets, at least as viewed from a US perspective, the oil markets were more concerning. Oil had a history of use as an instrument of foreign policy prior to World War II, and was even more so during and following the war. The US cut off supplies of oil to Japan in 1941 to encourage them to withdraw from China, and Arab states embargoed the US, the UK, and Germany following the 1967 war in Palestine (Crane et al. 2009). Though in neither case did the policy achieve the desired ends, the attempt served as a warning of things to come. In 1973, the Organization of the Petroleum Exporting Countries (OPEC) instituted a boycott against the US, Netherlands, and Portugal for supporting Israel in the Yom Kippur war. This time, in addition to the boycott, they also cut production which had the effect of driving oil prices from $3/barrel in 1972 to over $11 by early 1974. This time, the effort did have an effect. The US, lead by Henry Kissinger, undertook a program of shuttle diplomacy with Arab States that resulted in an end to the boycott and partial withdrawal of Israel from newly occupied territory (Crane et al. 2009). While in retrospect, a case can be made that embargoes have never been a threat to US energy security (Stern 2006), this was not the prevailing view in the 1970s. The US perceived itself as vulnerable to the "oil weapon".

As can be seen in Figure 11, by 1970 oil production in the US had peaked and was in decline. Since consumption continued to rise imports were also rising sharply.

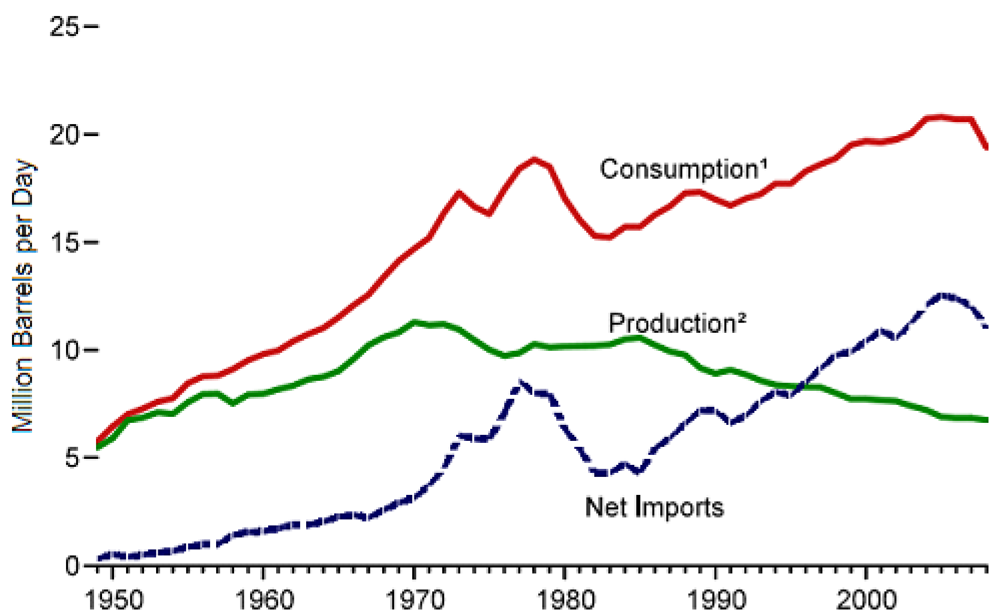


Figure 11. US crude oil overview 1949 - 2008 (EIA 2009b).

The combination of instability in the Middle East, higher oil imports, and higher oil and gasoline prices lead to a series of measures passed by Congress and signed by President Nixon. In 1973, Project Independence was announced. The stated goal of Project Independence was to achieve energy self-sufficiency for the United States by 1980 through a national commitment to energy conservation and development of alternative sources of energy. Nixon declared that American science, technology, and industry could free America from dependence on imported oil. Some of the important initiatives to emerge from Project

Independence included lowering highway speeds to 55 mph, converting oil power plants to coal, completion of the Trans-Alaskan pipeline, and diverting federal funds from highway construction to mass transit. The energy crisis led to greater interest in renewable energy especially solar power and wind power. It also led to greater pressure to exploit North American oil sources, and increased the US dependence on coal and nuclear power. This included increased interest in mass transit (Wikipedia 2010a).

During this period the United States Strategic Petroleum Reserve was created, and in 1977, the Corporate Average Fuel Economy (CAFE) standards were enacted by Congress. In 1976, the U.S. Congress created the Weatherization Assistance Program to help low-income homeowners and renters deal with rising heating costs by reducing their demand through advanced insulation. The cabinet-level Department of Energy was created, followed by passage of the National Energy Act of 1978.

The UNFCCC was not created until 1992. So as an action arena, it was not relevant during this time period. But environmental concerns were. Earth day was established in 1970 and by 1978 was a global annual event. The possibility of global warming or climate change was suggested already in 1906 in a paper by the Swedish chemist Svante Arrhenius (Arrhenius 1906). By the late 1970s climate models of increasing sophistication were under development (see for example Schneider 1975 or Ramanathan and Coakley 1978 for reviews) which showed the potential for significant warming as carbon dioxide in the atmosphere increased. Nevertheless, there was no particular action arena for climate, and climate was not yet central to any other arena.

The WTO was in full action as GATT, but as mentioned earlier agriculture was substantially excluded for early rounds, as was energy. Thus, we find in 1978 that the formal action arena the US government and two informal arenas - the grain market and the oil market - were the primary drivers relevant to bioethanol in the US.

3.2.2 Support for Biofuels

In 1978, commercial production of bioethanol in the US was virtually non-existent. As grain markets were generally favorable, there was little drive from the agriculture sector for alternative uses of grain, and, though energy prices were high and security concerns heightened, the cost of bioethanol was not competitive with oil based products and thus bioethanol plants did not attract investment.

As articulated by Gavett et al (1986) bioethanol did have some attractions:

- Available technology. Industrial and beverage ethanol industries had perfected the production process. In addition, corn wet-milling facilities can produce ethanol or high-fructose corn syrup, a sugar substitute.
- Short lead time. A fuel ethanol production facility can start up 11 to 26 months after construction begins, thereby presenting a relatively swift response to the threat of loss of supply of liquid fuels. Other

alternate fuels, such as shale oil and gasoline from coal, require far longer periods before economic quantities can be produced.

By 1977, events began to change in favor of bioethanol. Corn prices declined for the third year in a row and were now 30% lower than three years earlier (see Figure 12) and events in Iran were again causing concern about energy security. Bioethanol as a policy response appeared in the Food and Agriculture Act of 1977, which authorized loan guarantees of up to $15 million each for four ethanol from biomass pilot plants. Two ethanol plants were considered for financing under this program but neither was funded (Gavett et al. 1986).

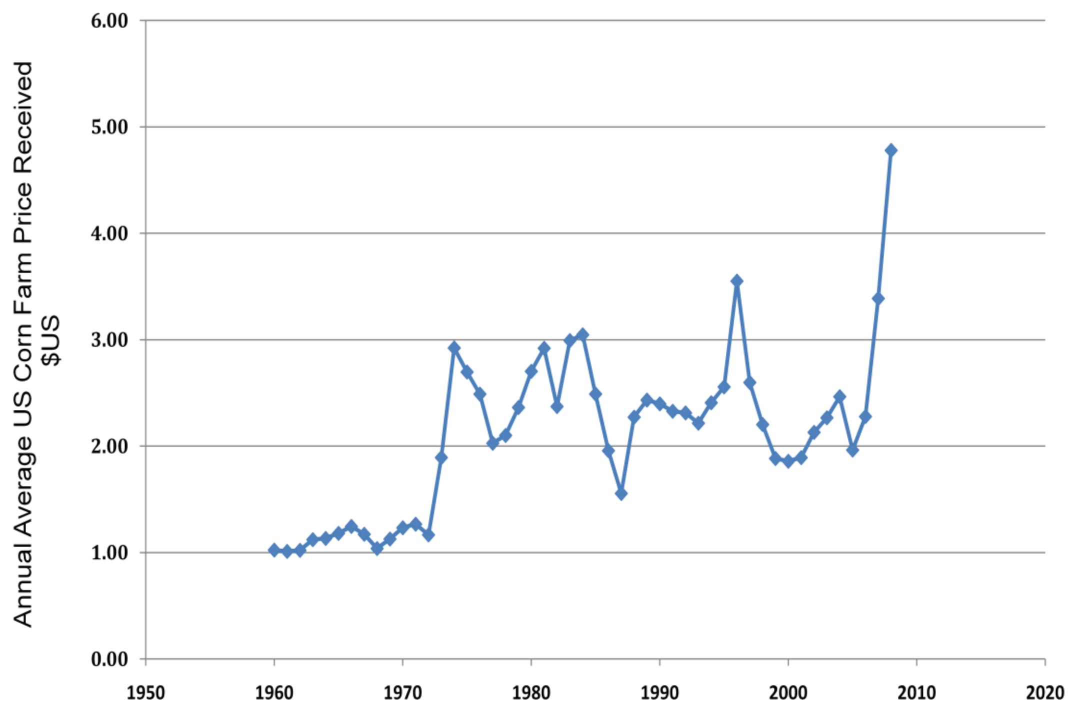


Figure 12. Annual average corn farm price in US (Farmdoc University of Illinois 2010c).

In the same year, President Carter took office pledging to address US energy security. In April, the President introduced an aggressive energy program designed to curb energy consumption and stimulate alternatives to foreign oil. In October, the much less ambitious National Energy Act of 1978 was passed, which was actually a package of several acts including the Energy Tax Act of 1978. Within the Energy Tax Act of 1978 was a provision that allowed ethanol blends of at least 10% by volume a $0.40 per gallon exemption from the federal motor fuels tax (McDonald 1979). This was the first time that ethanol was subsidized when produced from agricultural products. While the act was controversial, the ethanol subsidy was not and played no apparent role in its passage. In fact, in a multivariable analysis carried out by Uri (1980), the farm interest groups did not favor the Energy Act package largely because it raised energy prices.

The three action arenas present during this period are the US Federal government, the oil market, and the grain market. The grain market played out in the background through this period acting as a back drop for determining levels of rural income. In contrast, volatility and potential instability in the oil markets brought considerable pressure on the US Federal Government to seek alternatives to its dependence on foreign oil. The decades long concern for rural development and farm income caused the US Federal government to explore numerous policy options. The National Energy act of 1978 was one of those important policy options that created a new mechanism for supporting agriculture. This approach was particularly attractive since it was perceived over time to be able to address the foreign oil dependency problem, while simultaneously, through the potential for longer term price support, aided the grain markets. While the US Federal Government was clearly sensitive to actions in the grain and oil markets, and vice versa, there was little interaction between grain and oil markets. Oil pricing did, to an extent, impact grain production costs, but this factor was not a dominate one. Grain markets through biofuels had no impact on the oil markets. Biofuel volumes were simply too small to matter.

3.3 From 1978 TO 1989

This period ends with the passage of the Clean Air Act Amendments of 1990. During this time period, bioethanol from grain rises substantially, but remains a minor feature in the fuel market of the United States. It is more prominent as a policy option to support agricultural interests.

3.3.1 Exogenous Variables

The period begins well for corn markets and US producers. Production was generally trending upward (Figure 13), and exports (Figure 14) were strong as were prices (table 8). However, the situation rapidly deteriorated. Exports began a steep decline in 1980, falling by nearly 50% by 1985. With US production at an all time high, corn prices plummeted, falling from $3.21 in 1983 to $1.50 in 1986. Total net income from farming dropped to its lowest levels since 1933. Farm income per farm was lower than at any time since the mid-1960s. Loan delinquencies grew, and farmland values leveled off after tripling over the course of a decade. The 1981 Farm bill had been intended to save

Government funds, but in 1982 the weak farm economy brought a sharp increase in payments to farmers, back to the levels of the 1960s (Bowers et al. 1984).

Transfer payments rose rapidly and contributed significantly to the rising federal budget deficit. In 1985, the Congressional Budget Office (CBO) estimated that elimination of deficiency payments would save taxpayers $28.9 billion over five years (Johnson and Libecap 2001). Non-farm sectors of the economy were increasingly showing concern about the very large transfer payments to the agriculture sector, and the resulting pressure on the federal budget.

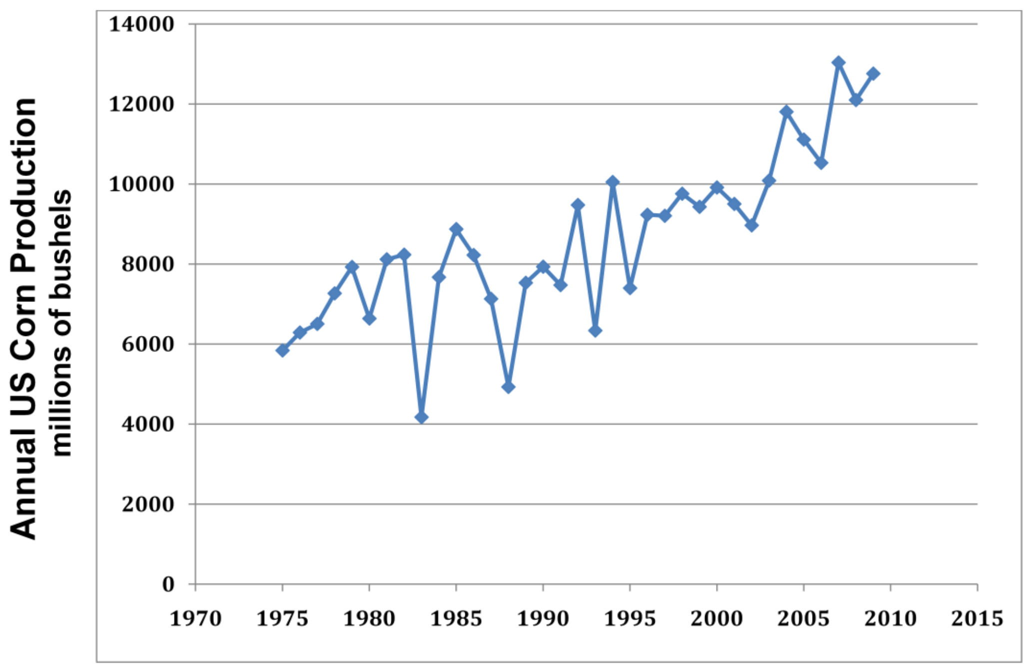


Figure 13. Annual US production of corn (Farmdoc University of Illinois 2010b).

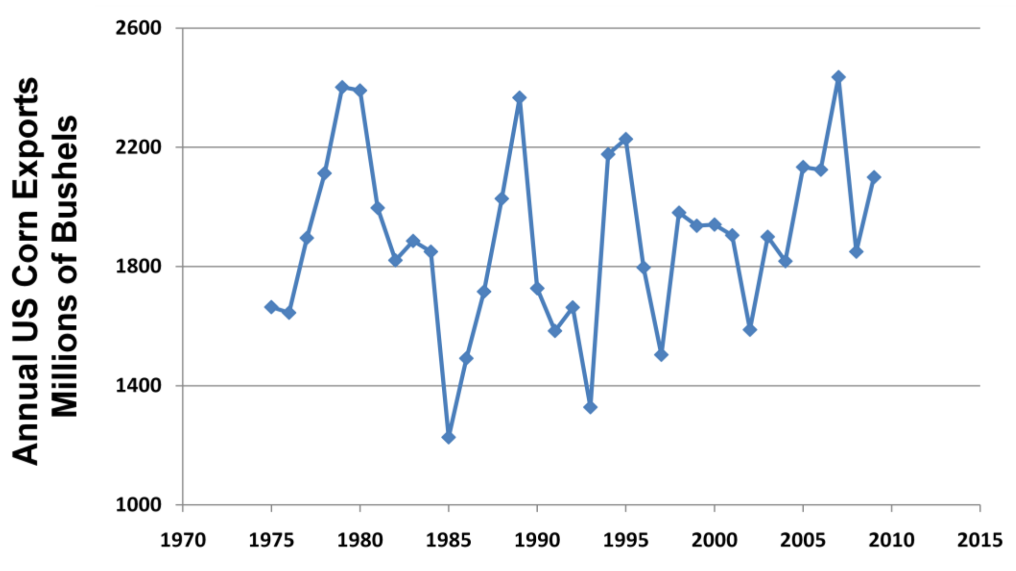


Figure 14. Annual US corn exports (Farmdoc University of Illinois 2010a).

Table 8. Corn price, target price and deficiency payment for US agriculture support programs (Johnson and Libecap 2001).

Year	U.S. Corn Prices ($/bu)	Target Price ($/bu)	Deficiency Payments ($millions)
1975	2.54	1.38	0
1976	2.15	1.57	0
1977	2.02	2.00	0
1978	2.25	2.10	88
1979	2.48	2.20	0
1980	3.12	2.35	0
1981	2.47	2.40	0
1982	2.55	2.70	291
1983	3.21	2.86	0
1984	2.63	3.03	1,653
1985	2.23	3.03	2,480
1986	1.50	3.03	6,195
1987	1.94	3.03	5,910
1988	2.54	2.93	2,163
1989	2.36	2.84	3,504
1990	2.28	2.75	3,014
1991	2.37	2.75	2,080
1992	2.07	2.75	3,625
1993	2.50	2.75	1,502
1994	2.26	2.75	3,199
1995	3.24	2.75	0,096

In the energy markets, oil prices rose early in the period largely due to events in Iran and Iraq in 1979 and 1980. The Iranian revolution resulted in the loss of more than 2 million barrels per day of oil production between November, 1978 and June, 1979. Subsequently, as Iran was weakened by the revolution, it was invaded by Iraq in September, 1980. By November the combined production of both countries was only a million barrels per day and 6.5 million barrels per day less than a year before. As a consequence, worldwide crude oil production was 10% lower than in 1979. The combination of the Iranian revolution, and the Iraq-Iran War, caused crude oil prices to more than double, increasing from $14 in 1978 to $35 per barrel in 1981(WTRG Economics 1999) .

Surging prices caused several reactions among consumers: better insulation in homes, more energy efficiency in industry, and automobiles with higher efficiency. These factors, along with a global recession, had caused a reduction in demand for crude oil. When combined with an increase in non-OPEC production, supply and demand became unbalanced, and prices began to fall. From 1982 to 1985, OPEC attempted to set production quotas low enough to stabilize prices. These attempts met with failure as members of OPEC produced beyond their quotas.

During most of this period Saudi Arabia acted to rebalance the market by cutting its production in an attempt to stem the free fall in prices. In August of 1985, the Saudis changed strategies and linked their oil price to the spot market for crude, and by early 1986, increased production from 2 million barrels per day to 5 million. Crude oil prices plummeted below $10 per barrel by mid-1986.

The rapid fall in itself was unsettling, as it created considerable stress within the oil industry especially in the United States. So much so that in April of 1986 then Vice-President George H. W. Bush traveled to Saudi Arabia to encourage the King to use the country's influence to stabilize oil prices.

According to Yergin (1991), on the eve of his trip, Bush said that he would "be selling very hard" to persuade the Saudis "of our own domestic interest and thus the interest of national security… I think it is essential that we talk about stability and that we not just have a continued free fall like a parachutist jumping out without a parachute." Bush added, "I happen to believe, and always have, that a strong domestic U.S. industry is in the national security interests, vital interests of this country." Following his meeting with the King, Yergin quotes Bush as saying, "There is some point at which the national security interest of the United States says, 'Hey, we must have a strong, viable domestic industry.' I've felt that way all my political life and I'm not going to start changing that at this juncture. I feel it, and I know the President of the United States feels it."

The US concerns were taken seriously, and during a summer of intense activity, Saudi Arabia worked out a broad agreement with both OPEC and non-OPEC members to agree to quotas or production limits in order to achieve a target price of $17 to $19 per barrel. By the end of 1986 an agreement was reached, and though prices continued to be volatile, and below the $18 target price (Figure 15), the decline was stopped, and prices sufficiently stabilized ending the political pressure in the market over the next several years.

In the mean time, ethanol as a motor fuel continued to grow very slowly (Figure 16), from about 2 thousand barrels in 1981 to 20 thousand in 1989. Little of consequence happened in the early part of the period, but in 1986, the US Department of Agriculture released a cost/benefit analysis, produced by a team lead by Earle Gavett a staff member of the USDA. As cited earlier, this report was scathing in its assessment of bioethanol. With pressure on transfer payments to farm interests already building, the report could not have come at a worse time. It immediately drew criticism from Congressional figures from districts highly dependent on corn. Representative Stallings of Idaho declared the study seriously flawed, and Senator Dole of Kansas introduced an amendment to the Farm Disaster Assistance Act of 1987 that required that the Secretary of Agriculture establish a seven-member panel to conduct a study of the cost-effectiveness of ethanol production (Johnson and Libecap 2001). The report of the panel did not actually establish the viability of bioethanol, but it did report optimistically about the potential for technology to reduce costs.

Other reports followed, with the repeated emphasis on the environmental and rural development benefits of bioethanol. Finally, a 1988 USDA report (LeBlanc and Reilly 1988) argued that with bioethanol production reaching 2.7 billion gallons by 1995, corn prices would increase substantially, reducing deficiency payments to such an extent that there would be a net savings to the government. This report concluded that ethanol could remain cost competitive as a blending agent as long as the existing fuel excise tax exemption remained in place. In the absence of the exemption, ethanol would struggle largely because of the glut in world petroleum markets, as mentioned earlier. The report did remark on the nonmarket benefits of ethanol in meeting environmental, energy security, and agricultural goals, but the benefits were limited as alternatives to ethanol were available. As a shadow of things to come, the report noted that "ethanol production is self-limiting in terms of its contribution to national energy supplies. Production levels of two or three times current levels, while still a small proportion of the total energy use, would begin to place strong upward pressure on corn and other grain prices ...". In 1988 ethanol production was 20 thousand barrels, or less than one tenth of the production of 2008. Finally, the authors suggested that ethanol as a blend stock could support some of the provisions of the Clean Air Act Amendments by reducing carbon monoxide emissions in automobiles, but that it would be best used in winter as the higher volatility of ethanol blended fuels increases ozone.

Among the formal action arenas, bioethanol remained a peripheral issue, but much was happening that would later have a major impact on biofuels. By the end of the 1970s, the scientific community was heavily engaged in the question of climate change. Evidence was clear that the earth's climate had changed in the past and there was some evidence that it could happen quickly. Though most of this work concerned global cooling and glaciations, in 1977, a study by the U.S. National Academy of Sciences focused on global warming from CO_2 emissions, warning of a future risk of rising seas and failures of agricultural and marine production (National Academy of Sciences 1977).

Though largely unrelated to the issue about global climate, a separate line of research brought the concern for anthropomorphic environmental change on a large scale firmly into the public conscious. In 1974, two scientists, Mario

Molina and Frank Rowland, noticed that certain gases produced by industry "CFCs" had long lifetimes in the atmosphere which enabled them to rise up to the stratosphere where ultraviolet rays would destroy them, and in the process create new species that destroyed ozone (Molina and Rowland 1974). The high, thin layer of ozone blocks the Sun's ultraviolet rays, so removing this layer could cause an increase of skin cancers, and perhaps bring still worse dangers to people, plants, and animals. CFCs were the propellants in aerosol sprays so every day millions of people were adding to the global harm as they used cans of deodorant or paint. Science journalists alerted the public, and environmentalists jumped on the issue.

In 1977, the U.S. Congress added restrictions on CFCs to the new Clean Air Act Amendments. A decade later, 40 industrial nations signed the Montreal Protocol which froze consumption of CFC's at 1986 levels by 1990, and aimed to decrease consumption 50% by 2000 (Wikipedia 2010c). In 1990 the London Agreement was signed, that brought total participants to 93 nations. And yet again in 1992, 87 industrial nations met in Copenhagen and agreed to a total phase-out of CFCs by January 1, 1996, and lesser developed countries were given until 2010 for full phase-out (Wikipedia 2010c).

Since the adoption of the Montreal Protoco, and subsequent treaties, emissions of CFCs have declined and atmospheric concentrations of the most significant compounds have also been declining. These substances are being gradually removed from the atmosphere. Nevertheless, complete recovery of the

Antarctic ozone layer will not occur until the year 2050 or later (Newman et al. 2006). The Montreal Protocol was the first international treaty regulating an air pollutant in history. The CFC/ozone story stands as an example of the ability for the international community to address a global problem.

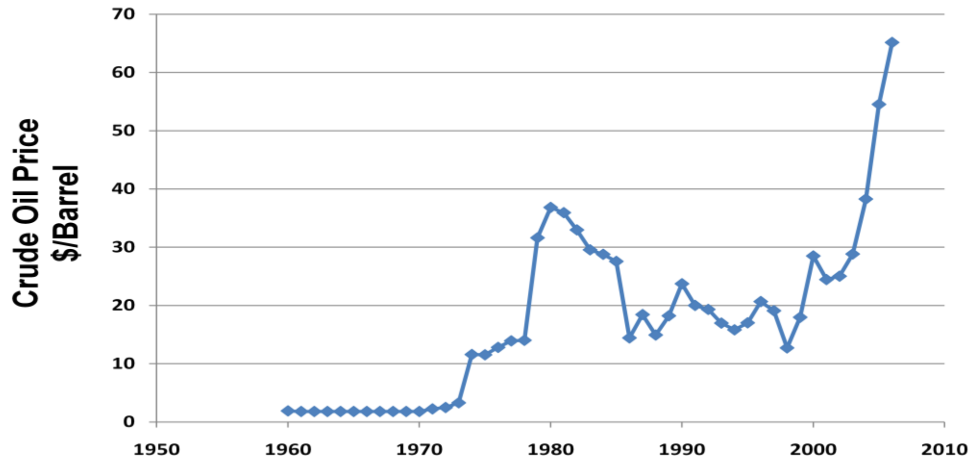


Figure 15. Annual average crude oil price (BP 2010).

3.3.2 Support for Biofuels

During this time period (1978-1989) bioethanol was substantially irrelevant to all the action arena's, with the exception of the U.S Government, where support coming from representatives of agriculture states remained strong. The rapid congressional reaction to the Gavett et al. (1986) study underscores the depth of that support. With support from Congress, bioethanol production increased from about 2 thousand barrels at the beginning of the period to about 20 thousand by the end of 1989, with over 50 ethanol production related facilities operating. Nevertheless, the industry continued to depend on Federal and State subsidies. And though a substantial increase, 20 thousand barrels remained less than 1% of all petroleum products used in transportation.

The apparent smooth growth at the industry level also masked considerable turmoil for individual companies and plants. The industry was unable to achieve consistent profitability because of changing economic conditions, especially the swings in corn and oil prices, and technological problems. Many plants were forced to default on loans, or were forced into bankruptcy, including most of the small plants that received Federal loan guarantees. Ethanol's use as an additive to gasoline to boost the oxygen content, became established during the period. Environmental benefits of oxygenated fuels, such as an ethanol/gasoline blend, led several states to develop oxygenated fuel programs. The first mandated program was instituted in the Denver, CO, metropolitan area and surrounding counties. The program led to an 8 to 11% reduction in ambient carbon monoxide levels (Stedman 1989). This and similar programs formed a component of regional air quality plans designed to bring ambient carbon monoxide levels below the standards established by the Clean Air Act Amendments. The use of bioethanol to meet the requirements of the Clean Air Act Amendments becomes a more important theme later.

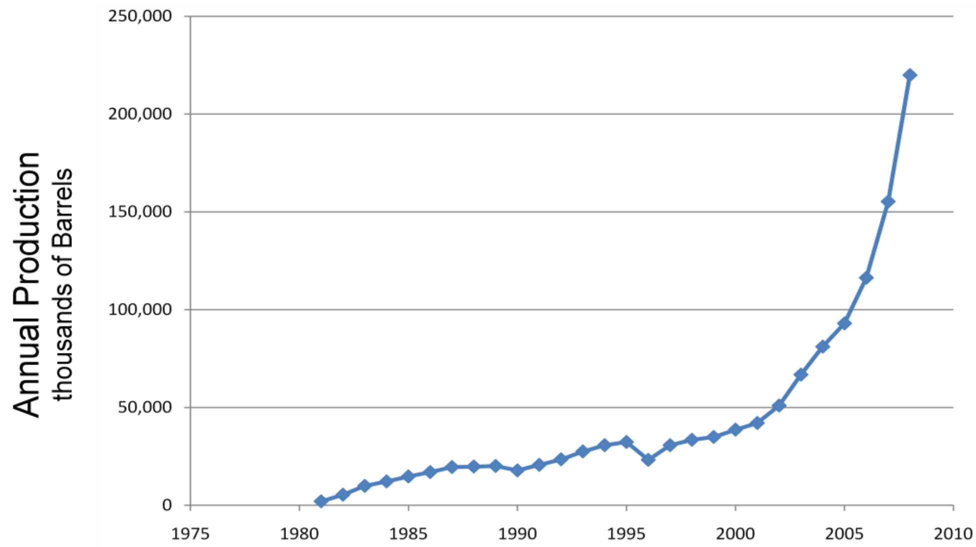


Figure 16. Fuel Ethanol Overview, 1981-2008. Annual U.S. production of fuel ethanol. Data does not include ethanol for purposes other than fuel (EIA 2008).

Again during this time period, the three important action arenas were the oil market, grain market, and Federal Government. The dynamic of the Pre 1978 time period continued into this time period, specifically instability and volatility in the oil markets, and substantial pressure on rural incomes, due to depressed prices in the grain markets. While the impact of corn ethanol on the grain and oil markets was minimal, the reverse was not the case. The volatility of these markets again made corn ethanol an attractive policy option even though analysis by the USDA showed little near or long term potential.

3.4 From 1990 TO 2004

This period ends with the Energy Act of 2005. During the period production of bioethanol rises from 20 thousand to 81 thousand barrels per year.

3.4.1 Exogenous Variables

Agricultural markets in 1990 were improved from the very difficult period in the late 1980s, but still remained generally unfavorable and volatile. As the period began, corn production (Figure 13), remained high, while exports fell (Figure 14). Actual prices fell well short of target prices (Table 8) resulting in a deficiency payment of over $3billion. In 1990, Congress passed The Food, Agriculture, Conservation, and Trade Act of 1990 (USDA 1990), as well as the Omnibus Budget Reconciliation Act of 1990 . Both acts built on the market-oriented foundation laid by the Food Security Act of 1985 (U.S. Congress 1985). These initiatives reinforced measures already under way to promote freer trade, reduce the deficit, and to move U.S. and world agriculture toward greater market orientation.

Pressure to cut the Federal budget deficit also played an important role. The main goals of 1990 farm legislation, food, agriculture, conservation, and trade act, were to further market orientation, reduce government spending on agricultural programs, help maintain farm income through expanding exports, and protect the environment. To lower budget expenditures and increase market orientation, the 1990 legislation reduced payment acreage and introduced planting flexibility. Producers could respond to market signals in their planting decisions because they could plant alternative crops on acres that were not eligible to receive income support payments (U.S. Congress 1990).

These efforts did not stem budget deficient problems, however, as deficiency payments remained high (Table 8). In 1996, following a "better" agriculture market year in 1995, Congress passed a new farm bill called the Federal Agricultural Improvement and Reform (FAIR) Act. The act made two major changes. First, it ended supply controls by eliminating provisions that made farm aid contingent on keeping land out of production. Second, it set up a seven-year schedule of fixed and declining direct farm payments completely de-linked from market prices. This change was intended to return agriculture in the United States to full market exposure over the seven year period (USDA 1996).

To further promote market mechanisms, official US government policy actively promoted liberalized international trade measures to open new markets for US products, including at the Uruguay Round of the WTO. This round of trade liberalization talks were completed in 1994, with new rules applicable to agriculture. Specifically, rules were agreed in three broad categories (WTO 2007).

The first category was market access. Barriers to trade such as quotas, variable levies, and voluntary export restraints to agri-food imports were replaced by a tariff-only system, and a country could not increase tariffs unilaterally. Tariffs were also reduced. Developed countries were required to reduce their tariffs by an average of 36% over six years, with a minimum cut in any one tariff line of 15% (WTO 2007).

The second category of new rules was for subsidies. Subsidies to farmers were classified according to their impact on production. Subsidies with minimal linkage to the quantities produced, the inputs used, or prices paid, were not affected, but most other subsidies were capped. Developed countries had to reduce agricultural subsidies by 20% over six years . (WTO 2007).

The final category was export subsidies. The agreement did not ban export subsidies, but imposed severe restrictions on the quantities subsidized and the amount of expenditure on these subsidies. New export subsidies are prohibited. The maximum expenditure on export subsidies in developed countries had to be reduced by 36%, and the maximum quantity of exports that can benefit from the subsidies had to be reduced by 21% over six years to 2000. (WTO 2007).

In spite of the changes to the international trade system, and US policy support, US corn exports did not rise above 1996 levels. Rather, exports fell sharply from 1996- 1997. From 1997 to 1998, there was a rise in exports. But from 1998 to 2000, began a slow decline to the end of the period (Figure 14). While commodity prices had been trending upward before the FAIR Act was passed, the 1996 corn price was a one year spike. Prices immediately began to plummet, and by 1999 were solidly below $2/bushel (Figure 12). Meanwhile, world prices followed the US prices downward. Prices of primary agricultural exports (corn, wheat, soybeans, cotton, and rice) declined by more than 40% from 1996 levels through 2003 (Ray et al. 2003).

Farm income from the marketplace declined dramatically globally. Congress responded by passing a series of emergency farm bills beginning in October 1998. Farmers received direct cash payments that were decoupled from any sort of production controls. The result was that the US output of corn first declined slightly, but then rose again to historically high levels (Figure 13). US net cash farm income remained relatively stable (Figure 17) but only because government payments ballooned from $7.5 billion in 1997 to $23.2 billion in 2000 before declining back to $13 billion in 2004 (USDA 2009).

The 2002 Farm Bill formalized these payments, which resulted in the agricultural sector receiving more aid than before the 1996 FAIR Act (Ray et al. 2003). The global decline brought considerable scrutiny onto US farm policy from the international community, and charges that agribusiness and corporate livestock producers were the real beneficiaries of a policy that was hurting farmers worldwide, but especially in developing countries (Ray et al. 2003). The international community saw the 2002 Farm Bill as a retreat from earlier United States positions on reforming farm policy and liberalizing agricultural trade. Now, the United States, appeared two-faced, telling the rest of the world to cut their farm subsidies while increasing its own (Thompson 2005).

The pressure on the United States continued into the next WTO round of negotiations, the Doha Round, which began in 2001 in Doha Qatar. Delegates in Doha believed that high-income countries tend to be most protectionist in the sectors where low income countries have a comparative advantage. These low income advantages occurred particularly with labor intensive manufactures and certain agricultural products. Since developing countries represented the majority of members of the WTO, any agreement in Doha would require that they clearly benefited. Continued reform of agriculture became a key feature of the Doha Development Agenda created by the conference (Thompson 2005).

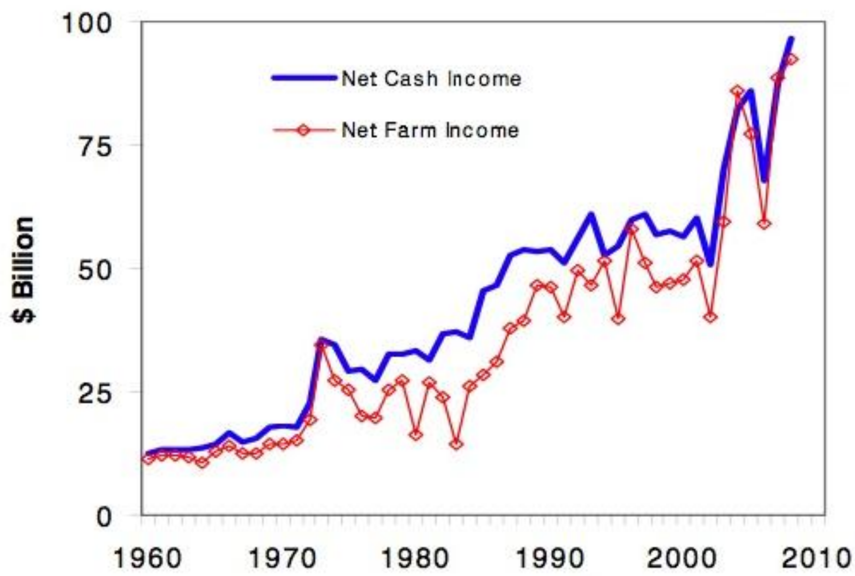


Figure 17. US farm income 1960 – 2008. Note: 2008 is estimated (USDA 2009).

For the oil markets, the period began with the invasion of Kuwait by Iraq in 1990. Prices rose briefly, but returned to prewar prices by 1991. Low prices where depressed further with the onset of the Asian financial crisis, which began in 1997. Prices were trending around about $20 per barrel, but in 1998 dipped briefly below $10 per barrel. Prices remained sufficiently low that a series of megamergers between independent oil companies began in 1998. More significantly, for energy markets a decade later, low prices pushed new exploration to historically low levels (Figure 18).

In 1999, OPEC agreed to a cut in production which began pushing prices higher as did the second Gulf War that began in 2003. Demand began to return especially in Asia by 2004, and prices began what would become a prolonged and historic rise.

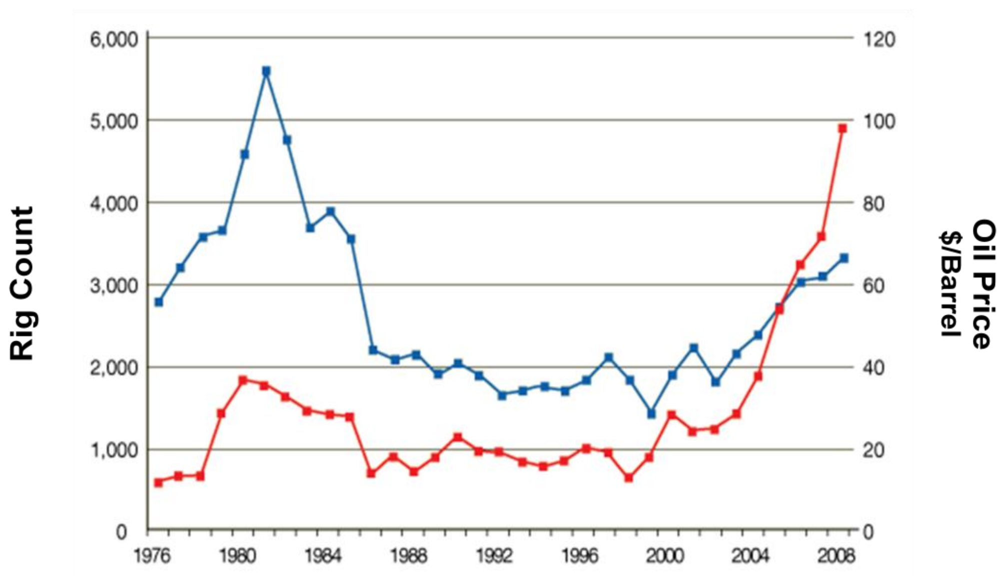


Figure 18. Worldwide rig count vs. crude oil price (1976 – 2008) (Baker Hughes Incorporated 2010, BP 2010). Red represents the oil price, and blue represents the rig count.

On the environmental front, concern about anthropogenic interference in the climate system through greenhouse gas emissions reached a sufficient level that the United Nations held the Conference on Environment and Development in June of 1992, which became known as the Earth Summit. The purpose of the conference was to agree to a treaty to stabilize atmospheric greenhouse gases.

The agreement that was reached is known as the United Nations Framework Convention on Climate Change (UNFCCC).

The treaty itself set no mandatory limits on greenhouse gas emissions and is legally non-binding. The treaty provided for updates that could be agreed to by a "Conference of the Parties" (COP). These updates, or protocols, were expected to set more rigorous standards. The best known of the protocols to date is the Kyoto Protocol, which set goals especially for developed countries, but they were again non-binding. The treaty entered into effect in 1994 and currently has 192 parties.

3.4.2 Support for Biofuels

Production of bioethanol continued to rise rapidly during the time period, as the market for MTBE declined following banning in several states, which opened up the opportunity for ethanol as an oxygenated fuel additive (see Table 9). The decline of 30,000 barrels from the peak of MTBE use in 1999 to 2004, was largely made up by bioethanol. Biofuel, and especially bioethanol, continued to benefit from stable government support in the form of subsidies (see Table 10).

Table 9. Annual production of MTBE (EIA 2009c).

Date	**U.S. MTBE Oxygenate Total Production (Thousand Barrels)**
1992	36828
1993	49528
1994	52490
1995	59670
1996	67752
1997	71933
1998	75072
1999	78826
2000	77460
2001	77510
2002	74604
2003	61274
2004	48100
2005	47374
2006	30698
2007	21706
2008	17319

Table 10. US federal government support for biofuels (Koplow, 2006; Duffield, 2008).

Support	Date Enacted	Authority
40¢/gal Tax Exemption	1978	Energy Tax Act of 1978
40¢/gal blenders credit*	1980	Crude Oil Windfall Profits Tax of 1980
Loans to small ethanol plants producing less than one million gallons per year	1980	The Energy Security Act
50¢/gal; 9¢/gal for ≥E85	1983	Surface Transportation Assistance Act
60¢/gal exemption	1984	Tax Reform Act of 1984
6¢/gal for ≥E85 of 1986	1986	Tax Reform Act
Credits to auto makers towards meeting CAFE standards for producing alternative and dual-fuel vehicles	1988	The Alternative Motor Fuels Act
54¢/gal blenders credit	1990	Omnibus Budget Reconciliation Act of 1990
2% oxygen required ethanol became a oxygenate for producers to blend with gasoline to meet air quality	1990	Clean Air ActAmendments; Oxygenated Fuels and Reformulated Gasoline Programs
54¢/gal net (4.16¢/gal of 7.7% blend; 3.08¢/gal of 5.7% blend)	1992	Energy Policy Act of 1992 (extended pro-rated exemptions to lower blends) of ethanol E5.7 and E7.7. Ethanol blends with diesel, and ethanol produced from natural gas
Title IX created a range of programs to promote bioenergy and bioproduct production and consumption.	2002	The Farm Security and Rural Investment Act of 2002
USDA made $150 million/yr available for ethanol and biodiesel producers who expanded production	2003-06	U.S. Department of Agriculture Commodity Credit Corporation (CCC) Bioenergy Program
53¢/gal	2001-02	Transportation Equity Act for the 21st Century initiated pre-scheduled reductions in the exemptions. Reduction set in 1997 by the Intermodal Surface Transportation Efficiency Act of 1997
52¢/gal	2003-04	
51¢/gal	2005-07	
51¢/gal	2005	American JOBS Creation Act of 2004 replaces the excise tax

		exemption with a Volumetric Ethanol Excise Tax Exemption
Renewable fuels standard requires a minimum amount of renewable fuel each year, starting at 4 billion gallons in 2006 and reaching 7.5 billion gallons in 2012.	2005	Energy Policy Act of 2005.
Expansion of the renewable fuel standard to 36 billion gallons a year of ethanol by 2022	2008	Energy Independence and Security Act of 2007

For the first time in my analysis all five action arenas are now present, and have a broad impact relevant to biofuels. The substantial concern about climate change and greenhouse gases, led directly to the creation of the UNFCCC following the Earth Summit in 1992. The UNFCCC, created the foundation for global policy making with respect to the climate. During this time period, the deliberations of the UNFCCC had minimal impact on the other action arenas, and, therefore, on corn ethanol. No direct linkages between corn ethanol and greenhouse gas reduction were actively promoted, but the stage was set for this linkage in the following time period. The WTO impact was also minimal on bioethanol, because no major policy options emerged supporting or not supporting bioethanol during this period. This is not the case for the US Federal Government, where the importance of both the UNFCCC and WTO action arenas on US policy was being felt.

The grain market was experiencing extreme volatility, and generally, downward pressure on farm incomes resulting in high federal budget deficits. For the first time in the scope of this analysis, the oil markets experienced relative geopolitical stability, but price volatility on the down side was unsettling for industry players. Security concerns were, therefore, substantially diminished compared to earlier periods. In spite of the reduced pressure on the Federal government regarding energy security, the emergence of the WTO and UNFCCC action arenas, combined with the extreme pressure coming from rural states because of low grain prices, led to a complex policy environment. This complex policy environment, in turn, led to a number of policy interventions in support of biofuels, see Table 10. Of particular note, is the Clean Air Act Amendments of 1990, that opened a way for ethanol as a fuel oxygenate. Other policy interventions included tax subsidies for blending and investment support for expanding production.

3.5 From 2005 To Present

3.5.1 Exogenous Variables

Corn prices began the period at about $2.00 per bushel, but rocketed to nearly $5.00 per bushel by 2008. Farm income fell in 2005 and 2006, before rebounding to historically high levels in 2008, as corn prices and commodity prices generally moved to unprecedented highs. The rise was so steep, that the higher food prices sparked riots in many countries in 2008, and according to the Food and Agriculture Organization of the United Nations (FAO), at least 40 governments imposed emergency measures, such as food price controls or export restrictions (FAO 2008).

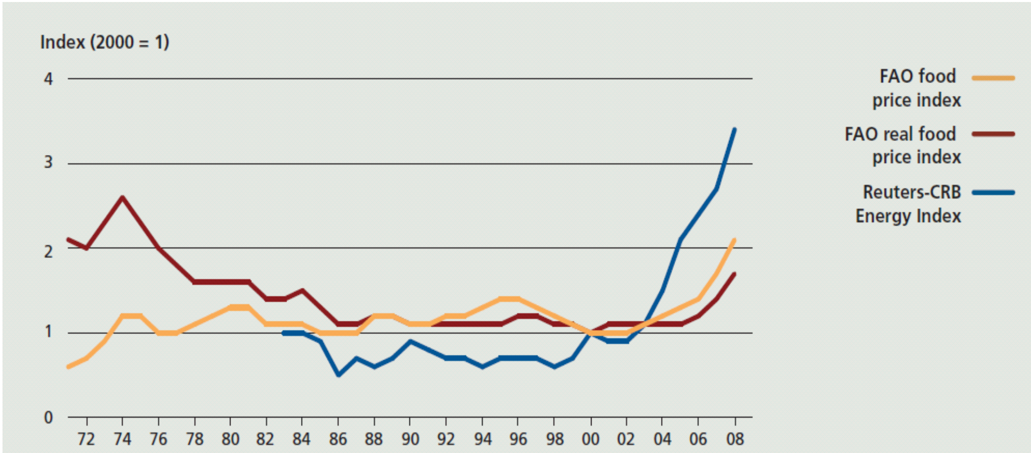


Figure 19. Long term food and energy price trends, real and nominal (FAO 2008).

The FAO index of nominal food prices doubled between 2002 and 2008. The nominal index reached its highest level in the last 3 decades. The real index, which is adjusted in order to assess how price increases affect consumers, showed its first substantial rise after four decades of decline (Figure 19). By mid- 2008, real food prices were 64% above the levels of 2002 (FAO 2008). Among the factors responsible for the rise in commodity prices were higher production costs, due to higher petroleum prices, production shortfalls, and strong demand growth – especially for biofuels.

In the Doha negotiations, the United States position was complex. On the one hand, most experts agreed that the US exceeded its support limits in 1999 and 2000, yet US negotiators continued to press for market opening reforms. The disconnect between Congress and the Bush administration negotiators arose largely because among farm organizations, there was little support for trade reform. Exports did not get a big boost from the Uruguay round agreements and remained volatile (Figure 14). Farm organizations saw more potential in biofuels than in exports. Without the support of farm organizations, there was no real incentive for Congress to make the changes in farm policy necessary to meet the spirit of Doha. The degree of misalignment became very apparent when Congress passed the 2008 Farm Bill, called the Food, Conservation, and Energy Act of 2008. This bill returned to many of the earlier farm support policies, and is generally seen to be non-compliant with the direction of Doha (Murphy and Suppan 2008).

The concern about climate reached a new level with the publication of the fourth assessment report of the IPCC in 2007. Some of the key conclusions of that report were (IPCC 2007):

- Warming of the climate system is unequivocal.
- Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic (human) greenhouse gas concentrations.
- Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized, although the likely amount of temperature and sea level rise varies greatly depending on the fossil intensity of human activity during the next century.
- The probability that this is caused by natural climatic processes alone is less than 5%.

- World temperatures could rise by between 1.1 and 6.4 °C (2.0 and 11.5 °F) during the 21st century and that:
- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium.

Contrary to what is often believed, Annex I countries have been on track to meet the Kyoto target of 5.2% reduction by 2012. The national inventories reported to the UN show an aggregate reduction of 3.9 % by the Annex I Parties, if changes from land use, land-use change and forestry are excluded and 5.2% if these affects are included (UNFCC Subsidiary Body For Implementation 2009). This level of reduction, however, is made up of widely varying reductions among individual countries and is trending upward (Figure 20).

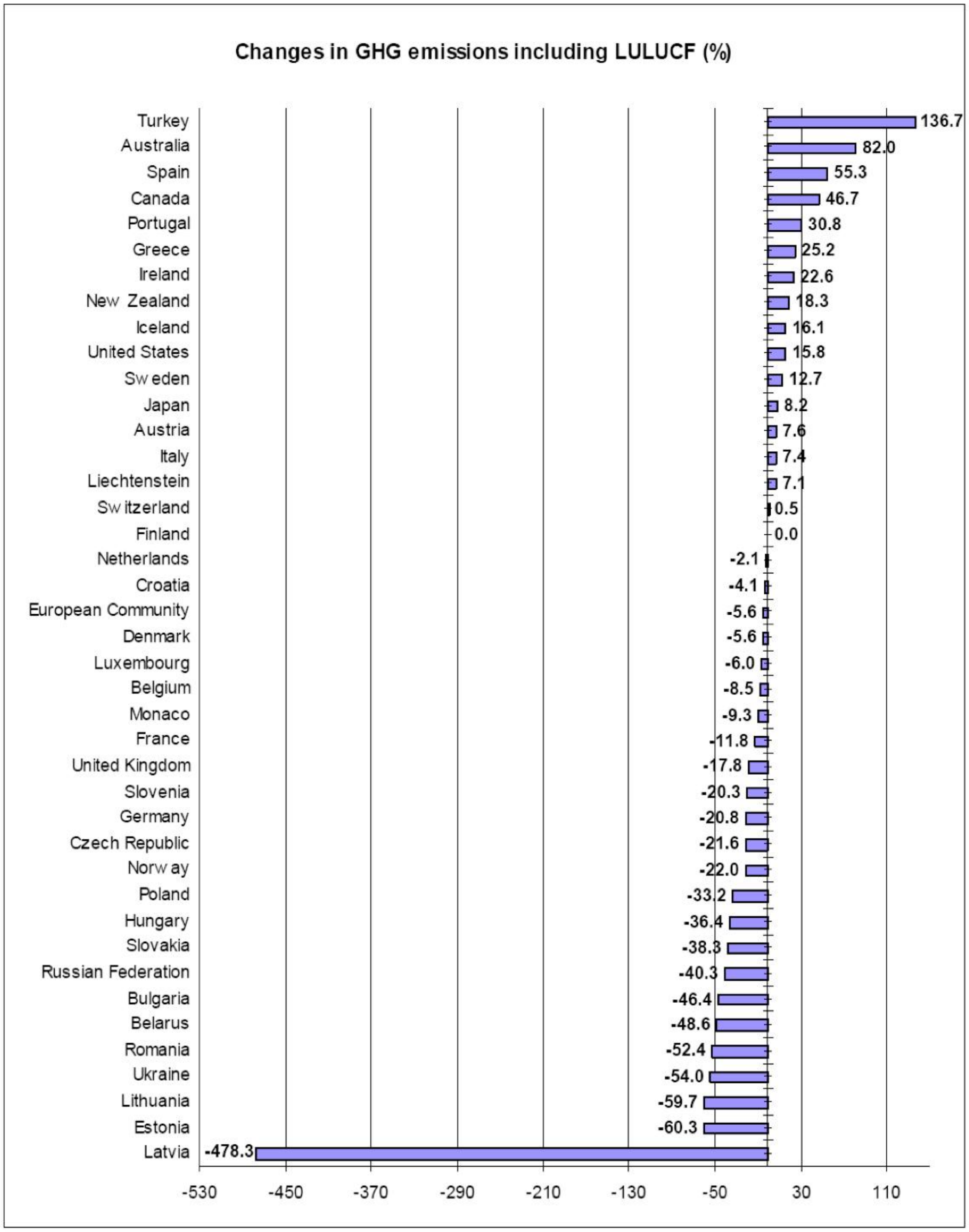


Figure 20. Changes in GHG emissions including LULUCF (%). LULUCF = land use, land-use change and forestry (UNFCC Subsidiary Body For Implementation 2009).

Total global emissions however continue rise. The US in particular has had a steep increase over this time period. Attempts to reinvigorate the UNFCCC process, and to reach a new accord with more aggressive targets that would bring total global emissions down, have thus far largely failed.

In the oil markets, the dramatic run up in price that began in 2005, and culminated in a price of more than $145 per barrel in July of 2008, before an even more precipitous decline, qualifies as one of the most extraordinary periods in the industry history. Much has been written about the cause of the spectacular rise and fall, but without a widely accepted conclusion.

A number of authors have argued it was largely a supply and demand phenomenon. Dees et al. (2008) for example, evaluated the time period between 2004 and 2006, and concluded that the price rise in that period was largely due to concern about supply. During the period, the world oil production capacity was operated at a higher than normal level, and when combined with market expectations that oil could be in short supply in the future, oil prices were pushed higher (Dees et al. 2008). Hamilton (2009), similarly argued that the price rise was the result of a supply/demand dynamic that went out of balance because of a failure of production capacity to keep pace with growing demand between 2005 and 2007. He points particularly to the lack of increase in production capacity in Saudi Arabia, and in fact, a decline in their output in 2007, as indicative of the problem. As with Dees, Hamilton (2009) points out the physiological effect on markets, of Saudi Arabia not balancing supply and demand, by adjusting both its production capacity and its monthly output. With demand from developing countries rising, and supply stagnate, price had to rise to push demand down enough to balance. The change in demand came from declines in Europe and the US.

Others, especially in the popular press, argued that the rapid rise in price resulted from speculation, particularly by hedge funds in the United States (see for example Krugman (2009)). Kaufmann and Ullman (2009), recently found a mechanism for how speculation in the futures market could be transmitted to the spot market, and thus, affect short term prices without building large inventories (Kaufmann and Ullman 2009).

Concern about speculation was sufficiently wide spread that investigations were undertaken by the US Senate Permanent Subcommittee on Investigations in 2006, where they found, "...there is substantial evidence supporting the conclusion that the large amount of speculation in the current market has significantly increased prices." The Commodity Futures Trading Commission in 2008, also undertook a study, but in a November 2009 statement, reported no evidence for excessive speculation.

Oil prices are currently at historically high levels, though well off the records set in 2008. The Energy Information Agency of the DOE, forecasts a price of $75 for 2010, and a 2030 reference case forecast of $130 per barrel real 2007 dollars.

Energy security came to the forefront again. The dislocation between where oil and gas reserves are located and where oil and gas are consumed heightened geopolitical concern. In his 2006, State of the Union address

President Bush put forward a goal to “replace more than 75% of our oil imports from the Middle East by 2025”. He went on to say that, “by applying the talent and technology of America, this country can dramatically improve our environment, move beyond a petroleum-based economy, and make our dependence on Middle Eastern oil a thing of the past.” During the 2008 Presidential campaign, both presidential candidates also made pledges to reduce dependence on foreign sources of oil. John McCain pledged to achieve “strategic independence” while Barack Obama pledged to reduce imports by an amount equivalent to the supplies coming from Venezuela and the Middle East. The geopolitical risk of dependence was exacerbated when Russia interrupted gas supply to the Ukraine, and thus Europe, in January of 2009.

Of particular importance to ethanol, was the change in law that required oxygenates for reformulated gasoline in the Energy Policy Act of 2005, and allowed companies to meet the clean air standards in any way they chose. In response, the oil companies made a big push to use ethanol in place of methyl-tertiary butyl ether, which was considered by some as highly toxic and was banned in many states. Demand for ethanol rose sharply as did the price. Ethanol reached an all time high wholesale price of $3.58/gal before falling back. The average wholesale price in 2009, fell below $2.00/gal for the first time since 2005 (Figure 21).

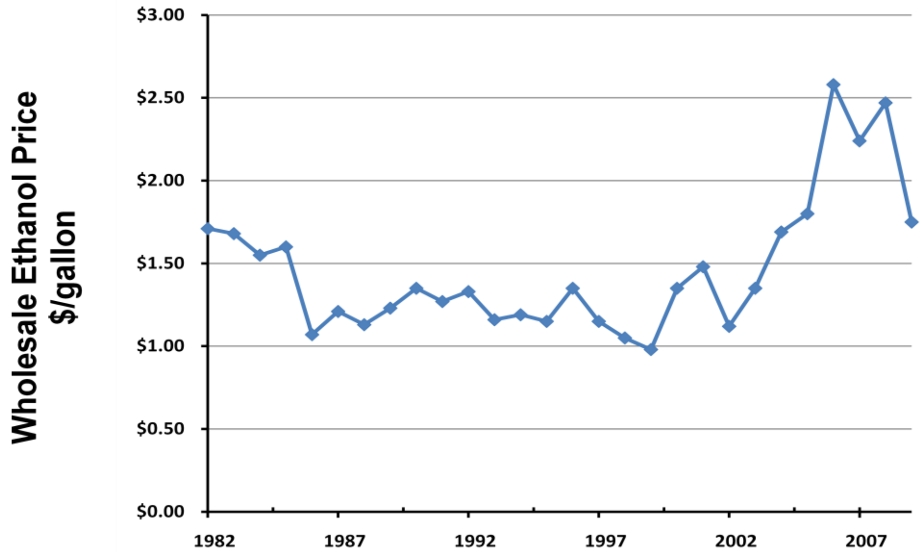


Figure 21. Average annual wholesale ethanol FOB price, Omaha, Nebraska, where the FOB price is the Free on Board price, which is the price actually charged at the point of loading (Official Nebraska Government Website 2010).

3.5.2 Support for Biofuels

Federal Government support for first generation biofuel remained strong. In his 2006 State of the Union address, President Bush put forward a goal to "replace more than 75% of our oil imports from the Middle East by 2025". He went on to say that "by applying the talent and technology of America, this country can dramatically improve our environment, move beyond a petroleum-based economy, and make our dependence on Middle Eastern oil a thing of the past." The Energy Policy Act of 2005, mandated the use of biofuels for transportation in the United States (See Table 11).

Table 11. Mandated Volumes of Renewable Fuel (Billions of gallons) under The Energy Policy Act of 2005 (U.S. Congress 2005).

Mandate Year	**Volume**
2006	4.0
2007	4.7
2008	5.4
2009	6.1
2010	6.8
2011	7.4
2012	7.5

The targets in the mandate are aggressive and are supported by subsidies for production that are large and have been in place for nearly 30 years to make investment in ethanol production attractive.

Yet, bioethanol has come under intense scrutiny over the last three years as scholars have explored both the contribution of bioethanol to greenhouse gas mitigation and energy security. While debate has been intense and results at times contradictory, a consensus seems to be emerging that bioethanol from corn makes only a very small contribution to both net energy or to greenhouse gas mitigation in the United States (Pimentel 2003, Hill et al. 2006, Tilman et al. 2006, Righelato and Spracklen 2007).

The small contribution to greenhouse gas mitigation may at first seem odd, as the fuel is derived from biomass that was itself created by plants fixing atmospheric carbon dioxide. While true, this renewable origin is only part of the story. Energy is expended in making ethanol from raw biomass which in the United States mainly comes from fossil fuels. Consuming these fuels both reduces the net energy benefit and releases greenhouse gases. Equally important, corn production requires large amounts of nitrogen fertilizers. According to Hill et al. (2006), when all factors are considered in a full cycle analysis, corn grain ethanol releases 88% of the net GHG emissions of production and combustion of an energetically equivalent amount of gasoline.

Turning then to energy benefit, the net energy benefit of corn derived ethanol has been hotly debated in the literature. Patzek et al. (2005) and Pimentel (2003), concluded that for corn ethanol the full cycle net energy benefit is negative. Subsequently, more work by other investigators has converged on a consensus view that the net energy benefit is positive but not large. The results of Hill et al. (2006), are indicative of the view that bioethanol from corn has a positive net benefit in the range of 25%, but that benefit is highly dependent on the energy benefit assigned to the byproduct distillers dried grain and solubles (DDGS).

Even with a positive benefit for energy and emissions, other authors have questioned the cost effectiveness of making the investments. Rubin et al. (2008), looked at the cost per ton of carbon dioxide reduction, and the cost per mBTU to reduce the use of fossil fuel and petroleum energy. Their results are shown in Table 12 below. The first thing to note from these results is the very large variation in cost to reduce fossil energy use and GHG emissions. In both cases, cellulosic ethanol produces much lower costs for reductions, and current ethanol production units are a very expensive way to make reductions. In contrast, the variation is not so large between technologies for reduction of petroleum use. This is probably not accidental, as the system of support for ethanol production is at least in part designed to replace oil imports.

Table 12. Current compensation provided by the blenders credit to services provided by different systems (Rubin et al. 2008).

Fuel Petroleum	**Technology/ Feedstock**	**FossilEnergy Reduction ($/mBtu)**	**Petroleum Energy Reduction ($/mBtu)**	**GHG Emission Reduction ($/ton)**
Avg. EtoH	Current	14.7	6.6	350.8
	Future	14.5	6.6	321.5
New EtoH	NG-DDGS	13.5	6.5	241.2
	NG-WDGS	10.4	6.5	175.4
	Coal-DDGS	17.0	6.6	*
	Coal-WDGS	11.4	6.6	367.5
Cellulosic EtoH	Switchgrass	6.0	6.5	79.6
	Corn Stover	6.0	6.4	78.7
Biodiesel	Soybean Oil	11.7	8.2	134.9

* GHG emissions increased compared to gasoline by using ethanol produced in natural gas or coal-fired plant that has co-products. WDGS = wet distillers grains with solubles. DDGS = dried distillers grains with solubles. NG = natural gas.

The second thing to note is just how high these costs are. The lowest cost for greenhouse gas reduction is just under $80/ton with technology not fully commercialized and with current technology estimated at about $350/ton. This compares with an early 2008 market price for one ton of carbon dioxide equivalent on the Chicago Climate Exchange of $1.90/ton for 2010 delivery and a 2006 estimate by McKinsey (Enkvist et al. 2007) that a $40/ton price for CO_2

emissions would be enough to stabilize atmospheric CO_2 at 450 ppm. Clearly, the market price falls short.

Researchers at Oak Ridge National Laboratory have examined the economic implications for energy security of imported oil (Greene and Leiby 2006, Leiby 2007). Greene and Leiby (2006), have examined a number of different analytical approaches to assessing quantitatively the economic cost of high imports. Leiby adopts and develops one of the approaches, a marginal cost approach, which considers the cost that would be caused by a marginal (small incremental) change in oil imports from the current level, and thus, is an indication of what price we should be willing to pay to achieve a small change. Marginal cost should be a simple guide for incremental policy. These researchers could only identify ranges of savings, as exact estimates are subject to assumptions that are not easily quantified. Even using the high estimates, however, the savings did not offset the costs of ethanol from corn subsidies.

In addition to the benefits for energy security and greenhouse gas emission reduction, supporters of biofuels also argued that they provided benefits to rural communities and farmers. Though support to rural communities, and especially farmers, are also seen as an important goal, just how the support for biofuel aids rural communities came into question. Rubin et al. 2008, argued that while legislation supporting biofuels tends to focus on energy security and the environment, the real reason for the broad support is support to farmers and landowners (Rubin et al. 2008). In his assessment, the only way to make sense of the size of the subsidies is as a mechanism to raise commodity prices and attract land currently fallow in set aside programs into production.

Miranoski (2007), argues along a similar line pointing out that higher commodities prices transfer money to farmers and landowners, and takes pressure off highly visible farm programs. Both of these lines of argument require that the ultimate beneficiary of the subsidy is the farmer and landowners. I make the distinction here between benefit from higher prices and benefit from the subsidy, as higher prices clearly benefit farmers and landowners, whereas subsidies may or may not depending on how rent is shared among corn producers, ethanol producers, and fuel blenders.

Analyses by Taheripour and Tyner (2007) and by Rubin et al. (2008), suggest that currently, and for the foreseeable future, the beneficiaries of the current subsidy is mainly the ethanol producer. They found that the impact on rural development is at best mixed, and may actually result in fewer jobs. With payments drawn from the general public in the form of lower tax revenues, and from future generations in the form of government debt, it is hard to justify why $7 to $9 billion should be transferred from these economic interests to ethanol producers for no net gain in social benefit.

An additional line of concern arose due to the very rapid run up in grain and food prices, i.e., the potential for food and fuel competition. Tilman et al. (2006), estimated that in 2005, 14.3% of the US corn harvest was used to produce 4.0 billion gallons of ethanol, which was energetically equivalent to just 1.72% of

U.S demand for gasoline. Johansson and Azar (2007), published the results of an economic model of the U.S. agricultural and energy system to assess the possible competition for land and to examine the link between carbon prices, the energy system, and food prices. Their results indicated that bioenergy plantations will be competitive on cropland already at carbon taxes about US $20/ton C. As the carbon tax increased, food prices more than doubled compared to the reference scenario in which there is no climate policy. They also found that, bioenergy plantations appropriate significant areas of both cropland and grazing land (Johansson and Azar 2007).

By 2008, the UN was sufficiently concerned to request a review of biofuels policy in the United States and Europe, because of the extremely high food prices. As reported by Rosenthal (2008), Jacques Diouf, the executive director of the United Nations Food and Agriculture Organization urged that current policies should be “urgently reviewed in order to preserve the goal of world food security, protect poor farmers, promote broad-based rural development and ensure environmental sustainability.”

This statement contrasted sharply with the views of the US Department of Agriculture which earlier released a study that showed "high energy prices, increasing global demand, drought and other factors -- not biofuels -- are the primary drivers of higher food costs." Secretary Schafer went on to say, "Developing diversity in our portfolio of fuels is if anything an even more urgent matter than it has been in the past. And it is one that remains central to our energy security and our national security," (USDA 2008).

That the USDA would come out squarely behind the production of biofuel and corn ethanol is perhaps not too surprising. A little more than a year earlier in his 2007 State of the Union address President Bush stated, “It’s in our vital interest to diversify America’s energy supply - the way forward is through technology. We must continue changing the way America generates electric power, by even greater use of …solar and wind energy...We must continue investing in new methods of producing ethanol, using everything from wood chips to grasses, to agricultural wastes…Let us build on the work we’ve done and reduce gasoline usage in the United States by 20% in the next 10 years...To reach this goal, we must increase the supply of alternative fuels, by setting a mandatory fuels standard to require 35 billion gallons of renewable and alternative fuels in 2017.” Following on from this challenge, Congress passed the Energy Independence and Security Act of 2007 in December 2007. A key provision of the Act is a major expansion of the renewable fuel standard (RFS) to thirty-six billion gallons a year of ethanol by 2022, with no more than fifteen billion gallons coming from corn or other grains and no less than twenty-one billion gallons coming from cellulosic feedstock in that final year.

The US Government stood solidly behind biofuels including bioethanol from grain, but the renewed emphasis on biofuels from non-food crops, which also appeared in the Energy Act of 2005, did signal a recognition that grain could not be the sole or even the majority feedstock for a meaningful biofuel industry in the United States.

In the period 2005 to present, all five action arenas are active and are interactive with each other. They are also all directly impacting on the role of biofuel and in particular grain ethanol as a fuel for reducing greenhouse gas emissions in transportation, and improving domestic and international energy security. One of the features of the interaction among the action arenas is we now begin to see is an element of friction. For example, big agriculture food manufacturers whose interests are better served by low to moderate grain prices bristled at the very high price spike of corn in 2008, and the perceived role corn ethanol played in it. This put the food manufacturers at odds with the federal government and their policy of supporting rapid growth of corn based ethanol. The extraordinary run up in oil price re-ignited energy security concerns and unlike previous crisis where geopolitical events in the Middle East were behind the spikes in price, this run up in price couldn't easily be attributed to any single factor. Rather, it seemed to be driven by a combination of factors including prolonged increases in demand for crude not matched by increases in investment to increase supply, aggressive oil trading practices by international firms, and a certain amount of "going with the herd". We also begin to see the impact of national policies in countries with large reserves that limited investment in the oil sector.

In the WTO, the Doha round now has as a core feature, agriculture reform. The US position in the Doha round was complex, and in the eyes of some inconsistent, since they tried to preserve farm subsidies while encouraging open trade with developing nations. Finally, the UNFCCC, and the focus the climate negotiations brought on greenhouse gas emissions, created a very complex environment for corn ethanol. While promoters of the fuel attempted to champion the green credentials of ethanol, a growing body of evidence suggested marginal benefits if any at all. Thus, the direction of UNFCCC research work, under the IPCC and in laboratories around the world, also brought this action arena into direct conflict with US Federal Government policy to promote corn ethanol.

CHAPTER 4

AN EMERGING SHIFT IN POLICY ON BIOFUELS

4.1 Introduction

In the last section we saw that in the United States there was a long history of support for corn based ethanol that could be understood in terms of the action arenas: US Federal Government, oil markets, grain markets, UNFCCC, and the WTO. Actions taken by participants in these arenas drove outcomes that lead to changes in policy and market dynamics. The relative importance of these arenas varied over time, but until the late 1990's they all tended to be aligned and significantly supportive of corn based ethanol in the United States. In the early 2000s, it became clear that the complications associated with first generation biofuels, and corn based ethanol in particular, were too numerous and too severe to overlook. All these complicating factors serve as exogenous variables into one or more of the action arenas. In this way, the outcomes of one become critical variables to another.

In this chapter, I will explore my second core question: There are calls coming from stakeholders to end support for first generation biofuels by governments. What is the justification for a shift in policy? I will explore in more detail the complications and criticisms in a global context. Also, I will show how these factors become exogenous variables to the action arenas, and how they impact policy shifts which are shaping the future of biofuels.

The primary criticisms of first generation biofuels largely fall into five broad categories: competition for food supplies, energy and net energy balance, land use change, net emissions savings, and competition for water. I will briefly review each.

4.2 Primary Criticisms of First Generation Biofuels

4.2.1 Competition for Food Supplies

Competition for food supplies, became an exogenous variable in several action arenas. It affected the grain market due to supply and demand and in particular the way that imbalances affected grain price. In the US Federal Government it set off a number of food versus fuel related investigations. Finally, it became an issue for the UNFCCC because of concerns over land use change. Competition for food supplies did not play as largely into the WTO, as the DOHA round negotiations were stalled during the large run up in food prices.

As noted above, biofuels were implicated in the extreme rise in food prices in 2008. The very real potential for bioenergy to draw down the world's biomass stocks and especially food stocks emerged. This raised concerns about food/fuel competition, and the potential for bioenergy to cause price increases in food commodities, or worse, actually drive food stocks for human consumption below safe levels, and take food supplies away from the world's poorest people (Boddiger 2007, Rist et al. 2009). Biofuels were, and to a certain extent still are, believed to be a source of rural development and empowerment by providing jobs for the poor nations and peoples (Boddiger 2007). However, increasingly negative reports concerning social justice especially with respect to access to adequate food supplies has emerged (Boddiger 2007, Charles et al. 2007, Runge and Senauer 2007, Rist et al. 2009).

Comestible biofuel crops pose a serious threat to the world's poor. While biofuel food crops provide additional income to farmers, especially in developing countries, these same farmers may also struggle to afford food due to escalating food prices (Boddiger 2007). Runge and Senauer (2007), estimated that if biofuel production continued business as usual, that the number of food insecure people "would rise by over 16 million for every percentage increase in the real price of staple foods." This would increase the number of the world's chronically hungry to 1.2 billion. They further reported that the use of cassava as a feed stock would increase its price by 33% by 2010 and 135% by 2020. Cassava is a staple in the poorest regions of sub-Saharan Africa, Asia, and Latin America.

In January 2007, Mexico's president Felipe Calderon was required to cap the prices for corn products due to increases in corn price. In late 2006, the price of tortilla flour in Mexico, who gets 80% of their corn from the U.S., doubled. The doubling in price occurred due to a combination of the U.S. corn price increasing from \$2.80 to \$4.20 a bushel, speculation, and hoarding (Runge and Senauer 2007). Vernon Eidman, of University of Minnesota, reported that higher feed costs will negatively affect the livestock and poultry industry by causing a steep fall in returns in these industries, particularly poultry and swine sectors. If these drops in return continue, Eidman projects, the price for poultry, pork, milk, and eggs will rise, and in the next few years, some of Iowa's pork producers may be forced out of business due to competition for corn from biofuels. Ultimately, these effects will be passed on to the consumer purchasing these foodstuffs (Runge and Senauer 2007).

Biofuels also have implications for the quality of the food supply. Some scientists have issue with biofuel co-products, which are used as a carbon offset. In some cases, such as corn, scientists have pointed out the potential of mycotoxins to become up to three times more concentrated in the co-products, distillers' dry grains, and wet distillers' grain. The toxins can cause serious health consequences for the poultry and livestock fed these products, which may cause further economic losses for the poultry and livestock industry (Biksey and Wu 2009).

4.2.2 Energy and Net Energy Balance

Energy and net energy balance are exogenous variables that played mainly into the US Federal Government action arena. Low net energy balance created concerns which altered the overall attractiveness of bioethanol as a replacement fuel, and its contribution to energy security.

Ethanol as a fuel is not as desirable as gasoline. The energy balance of ethanol to petrol is less than a 1:1 ratio. According to Brown (2003), on a volumetric basis, ethanol has only 66% of the thermal content of gasoline, thereby reducing the range of a vehicle operating solely on ethanol. Additionally, the hygroscopic nature of pure ethanol and its ability to mix with water, can lead to water-induced phase separation in gasoline blends, which is a drawback to this fuel type. If not kept completely isolated from the atmosphere, water can be absorbed, resulting in a lower layer composed primarily of water and an upper layer of hydrocarbon. This is a problem in blending and distribution. Thus, pipeline distribution and long-term ethanol storage creates many, but manageable issues. Of more importance, is the net energy benefit of ethanol.

The net energy benefit of corn derived ethanol has been hotly debated in the literature. Pimentel and co-authors concluded that for corn ethanol the full cycle net energy benefit is negative (Pimentel 2003, Patzek and Pimentel 2005). Subsequently, more work by other investigators has converged on a consensus view that the net energy benefit is positive, but not large. The results of Hill et al. (2006), are indicative of the view that bioethanol from corn has a positive net energy benefit in the range of 25%, but that benefit is highly dependent on the energy benefit assigned to the byproduct distillers dried grain and solubles (DDGS) (see Figure 22).

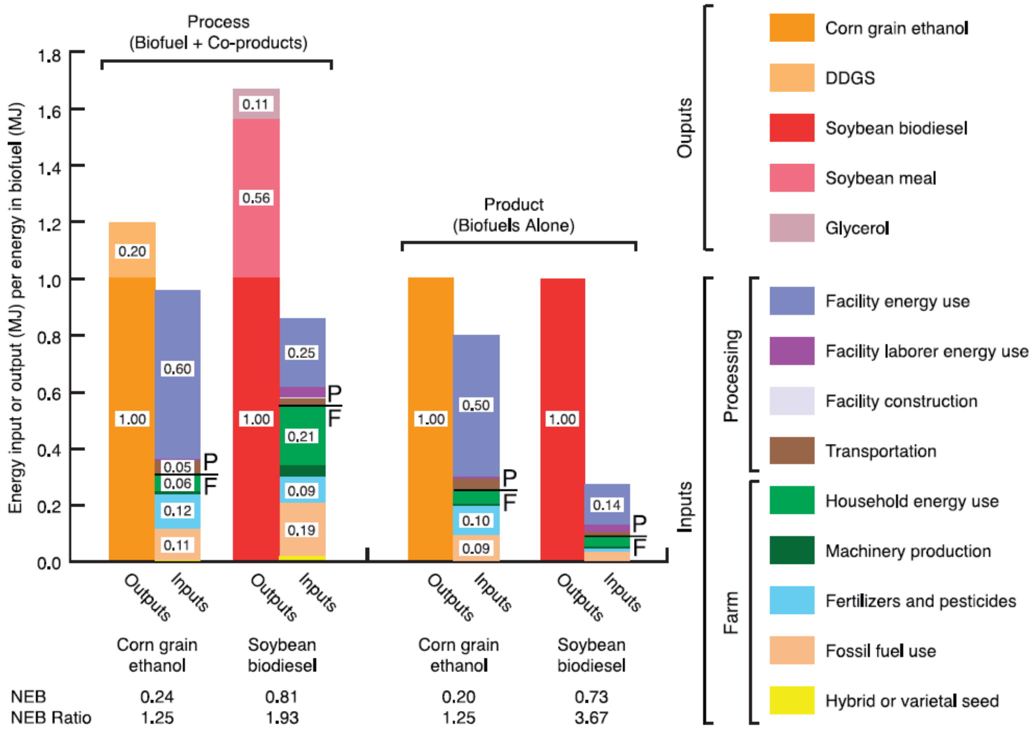
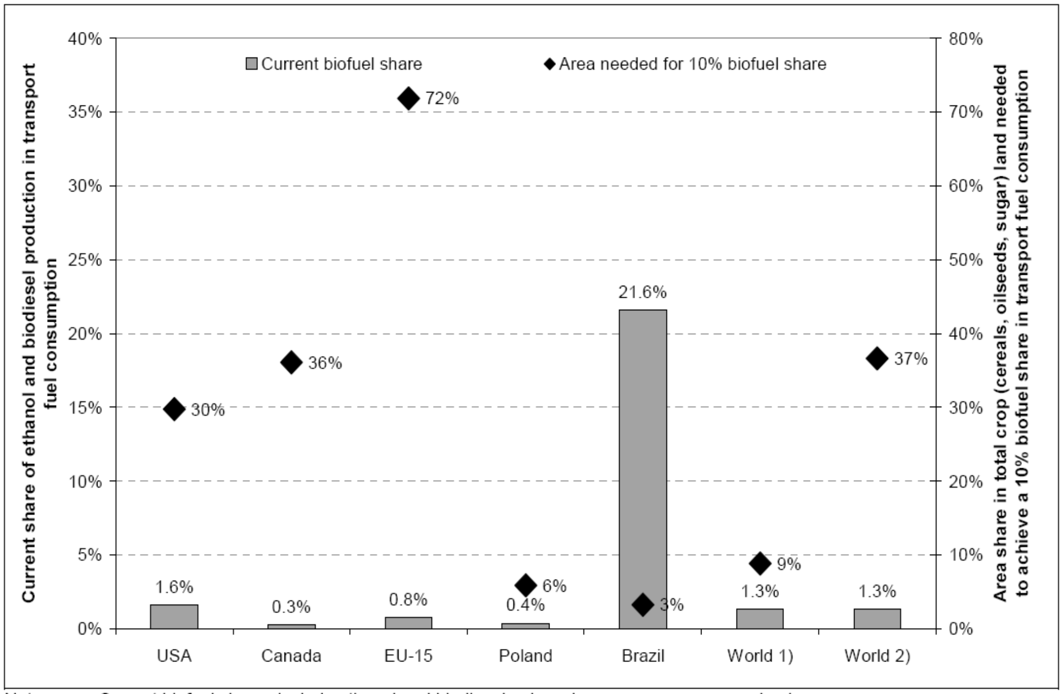


Figure 22. Energy balance for biofuels. NEB is the net energy benefit (Hill et al. 2006).

It should be noted, that net energy benefit alone is not the final indicator of the effect of bioethanol on energy security. The reason this is the case is because much of the energy used to produce bioethanol comes from coal and natural gas. Energy from fossil fuels is expended in making ethanol from raw biomass which reduces the net energy and greenhouse gases benefit. In effect, the corn ethanol system converts coal and natural gas, neither of which makes good transport fuels, into ethanol which is an acceptable transport fuel. Thus, while the net benefit may not be large, the substitution benefit is more meaningful.

Tilman et al. (2006), estimated that in 2005, 14.3% of the US corn harvest produced 14.8 billion liters (4 billion gallons) of ethanol, which was energetically equivalent to 1.72% of the U.S. requirement. While this is not a large fraction of the US requirement, the biofuels mandate for the US is 36 billion gallons by 2022, most of which will come from ethanol. 36 bilion gallons corresponds to about 136 billion liters. Since gasoline is produced exclusively from oil, ethanol would indirectly substitute for oil imports. At a level of 36 billion gallons, substitution could begin to be meaningful in considering oil pricing, and it certainly would be at 136 billion liters (110th U.S. Congress. 2007).

Based on the use of corn for ethanol in 2005, Tilman extrapolated to determine that the entire 2005 U.S. corn and soybean crop would have offset 12% and 6.0% of U.S. gasoline and diesel demand, respectively. When energy of production was taken into account a net energy gain equivalent to 2.4% and 2.9% of U.S. gasoline and diesel was all that would have been achieved. Perhaps 15% of the US corn crop and 2% of soybeans can be sustainably turned over to fuel production, but certainly the entire crop cannot be, even in the service of national security and especially for such a small gain. Von Lampe (2006), has made similar estimates for land use requirements for replacing 10% of petroleum motor fuels with biofuels in other countries (Figure 23).



Notes: Current biofuel shares include ethanol and biodiesel only – shares are on an energy basis.
World area shares are calculated relative to land used for cereals, oilseeds and sugar globally (World [1)]) and within the five major biofuel producing regions only (World [2)]).
All areas requirements are calculated on the basis of average crop area and yield data for 2000-2004 and transport fuel consumption in 2004. For these calculations, the 2004 shares in the feedstock mix are assumed to remain unchanged. Details on the calculations can be found in Annex 2.
Note that calculations for the EU exclude ethanol transformed from wine which represented about 18% of EU ethanol production in 2004.

Figure 23. Biofuel shares in transport fuel consumption and land requirements for 10% biofuel shares in major biofuel producing regions (Von Lampe 2006).

In developing countries with small demand for motor fuel and large land areas (Brazil and Poland), the requirement for land is not outrageous 3% for Brazil and 6% for Poland, but 30% for the US and 72% for the EU-15 is unrealistic (Von Lampe 2006).

4.2.3 Land-Use Change

Land use change was an exogenous variable largely into the UNFCCC action arena, although awareness within the US Federal Government of the potential for very serious negative consequences of indirect land use change was real. Of particular concern, was land clearance in developing countries for food crops redirected in the US toward biofuel production. The greenhouse gas emissions associated with land clearance can be very large as noted earlier in this thesis.

New markets, food shortages, and higher prices are key market drivers which not surprisingly stimulate farmers to respond ultimately through intensification to drive up yields, or through expansion by converting land from other uses to the production of bioenergy crops or food and fodder. The affect is direct in the case of plant foodstuffs for human consumption, but indirect as the livestock and poultry industry are affected by the use of fodder for biofuel production. A new source of demand for animal feed will either drive up costs for fodder, which will be passed onto the consumer, or require further land clearance to accommodate the land lost to the biofuel feedstock. This latter effect, though signaled by ecologists, was not well understood when policies were set in the US and Europe. Since then, it has become clear that commodity price signals originating in the US and Europe can and probably do drive land use changes as far away as South America and South Asia. When the land use changes involve widespread deforestation or conversion of wetlands, the environmental consequences can be dire –far out weighing any of the primary benefits of biofuel. Additionally, the intuitive expectation that biofuels would reduce emissions of greenhouse gases proved not universally true. The source of the biomass, GHG balances associated with land conversion (Righelato and Spracklen 2007, Melillo et al. 2009), and the land resources/inputs used to grow biomass, all matter (Charles et al. 2007).

Other emergent issues are land rights in agricultural expansion and adoption of "abandoned and degraded" land. It is not uncommon in poor nations that perceived abandoned land actually to be in use by poor locals, or to act as important habitat for native species. Additionally, large commercial agriculture can often out-compete small local farmers (Boddiger 2007, Rist et al. 2009) and effectively push them out of lands they traditionally occupied. Also, degraded land often requires higher use of fertilizers, herbicides, pesticides, and fungicides to boost productivity to commercially attractive levels (Patzek et al., 2005, Spangenberg and Settele 2009). This change in practice can have environmental consequences, and does have an impact on net emissions of greenhouse gases. Pesticide, herbicides, and fungicides are associated with the destruction of flora and fauna and are commonly toxic to humans, while increased use of fertilizers often leads to eutrophication and higher emissions of nitrogen oxides.

4.2.4 Net Emissions Savings

Net emissions savings are an exogenous variable in the US Federal Government and UNFCCC. Greenhouse gas abatement was one reason why bioethanol was supported by both action arenas initially. Given that net emissions savings for corn bioethanol was little to none, support for the fuel in the UNFCCC became largely non-existent, and in the US Federal Government this reality created policy complications.

While again debate has been intense and results at times contradictory, a consensus seems to be emerging that bioethanol from corn makes only a very small contribution to greenhouse gas mitigation in the United States. The disadvantages for corn ethanol are the need for large inputs (such as process heat, fertilizer, pesticides, and water). Some scientists, like Pimental, argue that the inputs simply outweigh the outputs. According to Hill et al. 2006, "N fertilization can cause microbial mediated production and release of N_2O, which is a potent GHG", in combination with nitrogen runoff associated with fertilizer usage, which also releases N_2O, any GHG gains of the biofuel itself are largely lost (Patzek et al. 2005, Spangenberg and Settele 2009).

Farrel et al. (2006), created Figures 24, 25, and 26, comparing the various energy inputs and related GHGs emission measurements for different studies. Scientists contributing studies included Pimentel, Patzek, Graboski, de Oliveira, Wang and Shapouri. Not surprisingly, the values ranged significantly between studies. Some reported ethanol produced notably less GHGs than gasoline (Shapouri and Wang), while others reported notably more (Pimental). A similar disparity was found with petroleum inputs with Pimental reporting higher values and Shapouri the lowest values. Following the publication of Farrel et al. (2006), the journal Science published an erratum beneath the article. The Ethanol Today values were corrected after it was realized the lime application in their study had been miscalculated and uncertainties emerged regarding the emissions factor of lime and nitrous oxide resulting from nitrogen fertilizer application. This changed the point estimate of net GHGs for corn ethanol to 18% below conventional gasoline rather than 15%. However, the uncertainty band expanded to -36% to +29%.

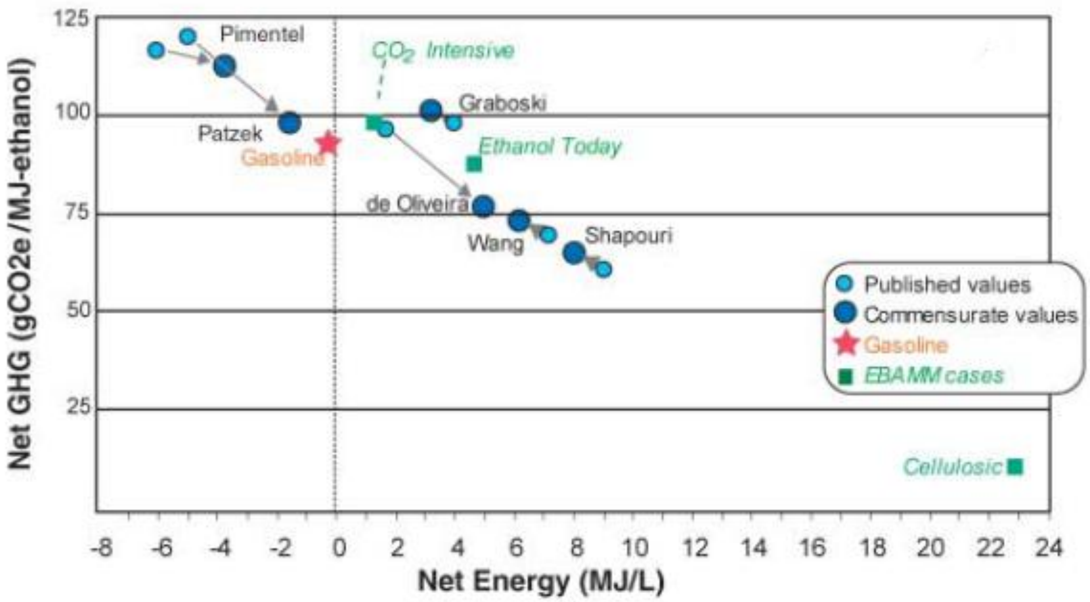


Figure 24. Ethanol's net energy and net greenhouse gases for six studies and three cases (Farrell et al. 2006). Small light blue circles are reported data that include incommensurate assumptions, whereas the large dark blue circles are adjusted values that use identical system boundaries. The Energy and Resources Group Biofuel Analysis Meta-Model (EBAMM) was used to create a direct comparison of the data and assumptions across the studies.

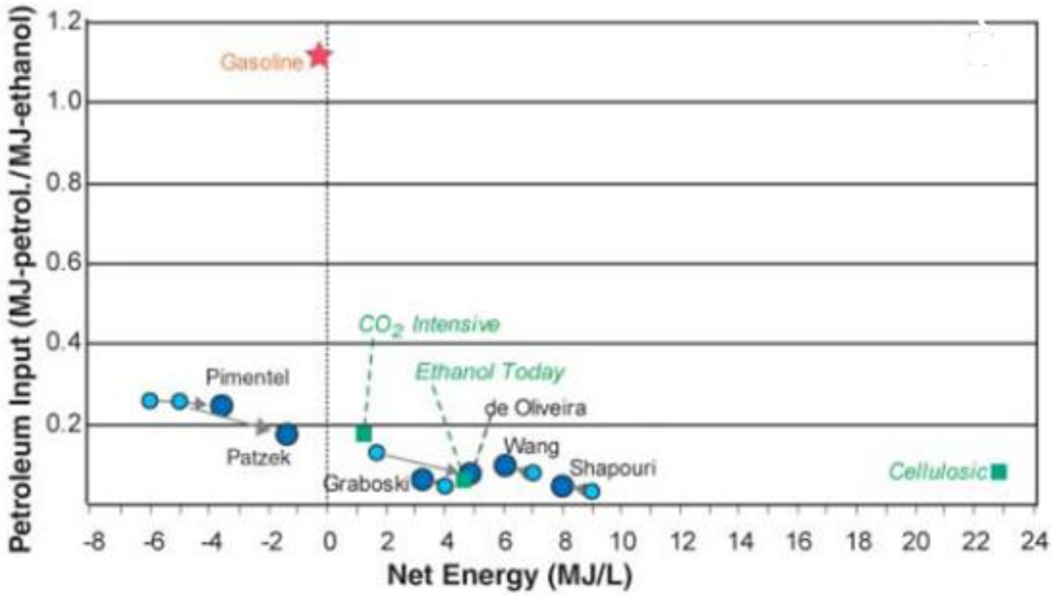


Figure 25. Ethanol's net energy and petroleum input for six studies and three cases (Farrell et al. 2006). As in Figure 24, small light blue circles are reported data that include incommensurate assumptions, whereas the large dark blue circles are adjusted values that use identical system boundaries. The Energy and Resources Group Biofuel Analysis Meta-Model (EBAMM) was used to create a direct comparison of the data and assumptions across the studies.

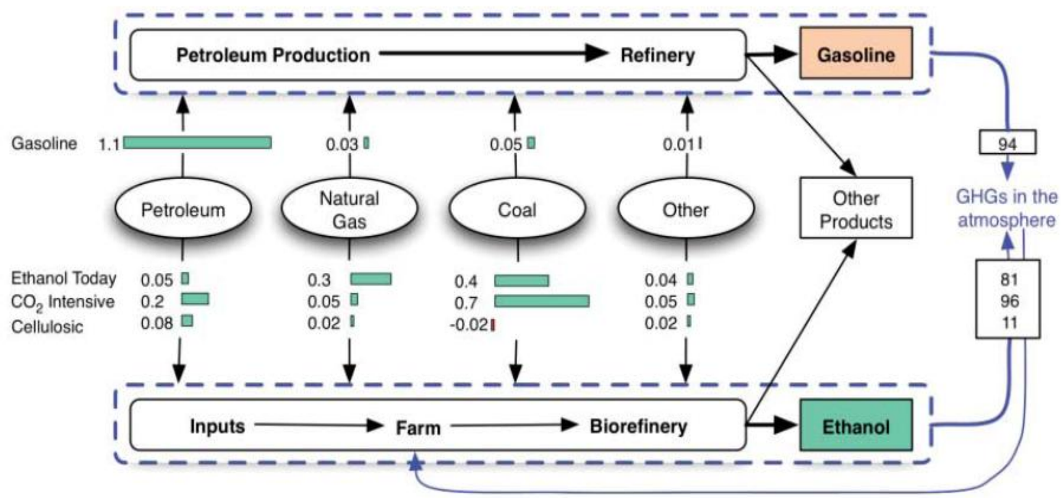


Figure 26. Alternative metrics for evaluating ethanol based on the intensity or primary energy inputs (MJ) per MJ of fuel and of net greenhouse gas emissions (kg CO2-equivalent) per MJ of fuel (Farrell et al. 2006).

Fargione et al. (2008), conducted a study analyzing the carbon debt associated with converting rainforests, peatlands, savannas, or grasslands to produce food crop–based biofuels in Brazil, Southeast Asia, and the United States (Figure 27). The authors calculated, that soils and plant biomass are the two largest biologically active stores of terrestrial carbon. Combined, soils and biomass contain roughly 2.7 times more carbon than the atmosphere. However, this CO_2 is released during conversion of native habitats to cropland. This occurs as a result of burning, or microbial decomposition of organic carbon, that had been stored in the plant biomass and soils. Fargione et al. (2008), call the amount of CO_2 released during the first 50 years of this process the “carbon debt” of land conversion. Biofuels can eventually repay this debt if they have net GHG emissions lower than the life cycle emissions of the fossil fuels they replace. The study concluded that biofuels produced in the United States, Brazil, and Southeast Asia would create a carbon debt releasing 17 to 420 times more CO_2 than the annual GHG savings that they would provide by displacing fossil fuels. It would take 48 years for corn ethanol produced on U.S. cropland to repay its carbon debt, and 93 years for corn ethanol produced on converted grasslands. The debt incurred by palm oil produced in peatland rainforest in Malaysia and Indonesia would take over 400 years to repay. However, waste biomass or biomass grown from perennials on degraded or abandoned agricultural land, incurred little or no carbon debt and offered immediate sustainable GHG advantages (Fargione et al. 2008).

Searchinger et al. (2008) analyzed land conversion, in a similar manner to Fargione et al. (2008), but also recognized that biofuels cause an additional indirect demand for land use change. Theoretically, the agricultural land diverted to create biofuels causes conversion of more natural land for displaced food crops. The authors calculated that a 15 billion gallon expansion of U.S. corn ethanol production would require 26.7 million acres of new cultivated land. Over a 30 year period, this would double CO_2 emissions relative to fossil fuels. Additionally, the carbon debt from this conversion and production would take 167 years for corn ethanol to repay.

Therefore, given the issues with land conversion and inputs associated with biofuel use, in many cases restoring natural vegetation and forests provide a better carbon offset than clearing land for biofuel production, which is associated with a huge upfront carbon loss (Righelato and Spracklen 2007).

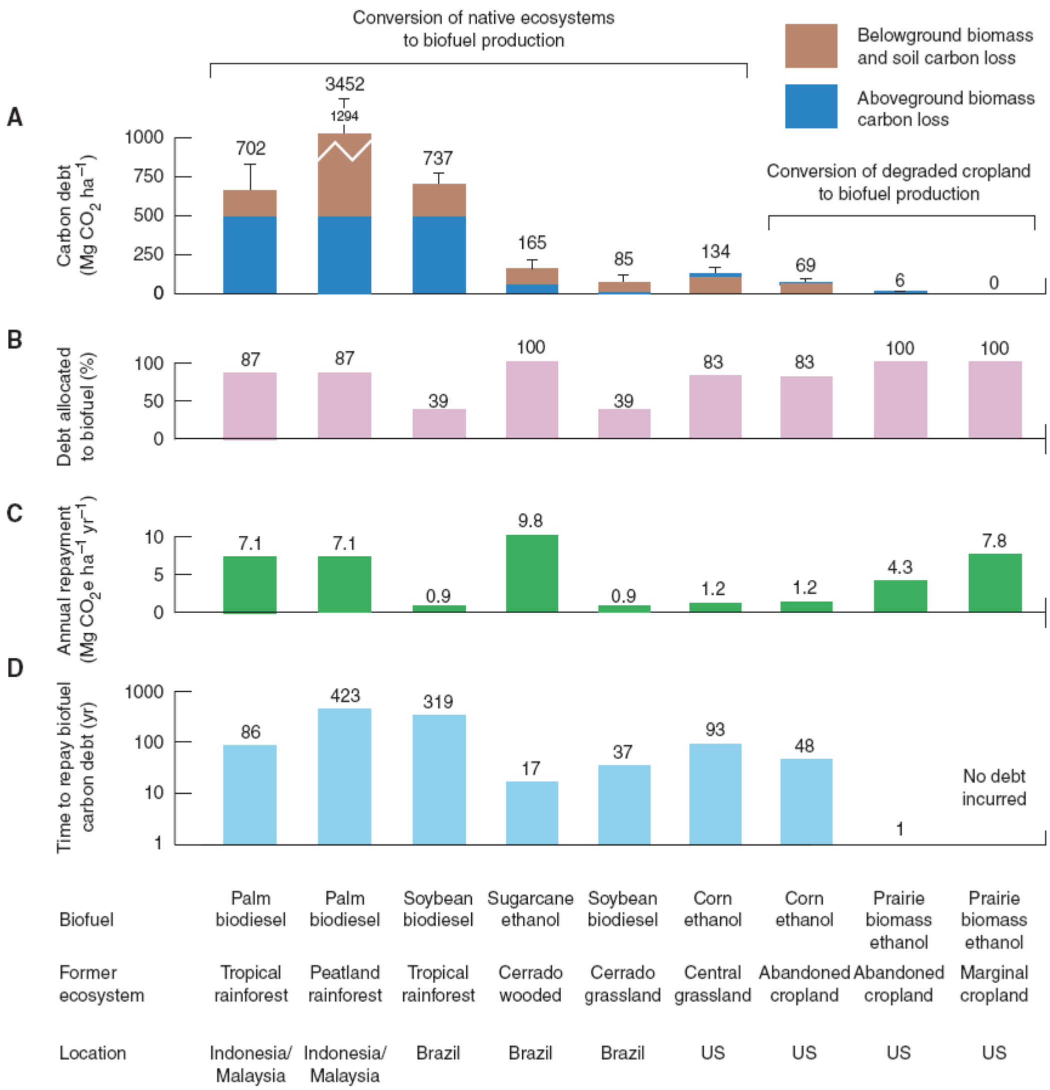


Figure 27. Carbon debt and land conversion (Fargione et al. 2008).

4.2.5 Competition for Water

Competition for water is an exogenous variable for the US Federal Government. Presently, it is not a major policy driver for biofuels, but it is widely expected to become a substantial issue in the not too distant future.

Koh and Ghazoul (2008), reported on a study presented by (WWAP – UNESCO, 2006) that observed pressure on water resources is increasing globally due to population growth, rural-to-urban and trans boundary migrations, climate change, natural disasters, poverty, and warfare. The water crisis is exacerbated in developing countries, where there is a dearth of clean water and sanitation commonly resulting in malnutrition, disease, and death (Pickett et al. 2008).

Water is also a critical part of biofuel production. It is required in both the production of feedstock and the conversion of biomass to fuel (Boddiger 2007, Charles et al. 2007, de Fraiture et al. 2008, Koh and Ghazoul 2008, Sexton et al. 2009, Tilman et al. 2009). The need for irrigation and the amount varies based on the crop type and local climate. Sexton et al. (2009), reported on a study conducted by Serageldin (2001), that placed the average water consumption for corn feedstocks at 1,527 gallons of water per gallon of ethanol produced (Figure 29). This value was compared with the 1,320 gallons of water required to produce the daily food requirements for an average diet in North America (Serageldin 2001, Sexton et al. 2009). Further work conducted by Pate et al. (2007) and Phillips et al. (2007), and reported by Koh and Ghazoul (2008), estimated that biorefineries consume 4 gallons of process water per gallon of bioethanol produced (gal/gal). It was thought that the losses occurred from evaporation during the distillation of ethanol following fermentation. Water use associated with petroleum refining was reported at 1.5 gal/gal by Pate et al., 2007 (Koh and Ghazoul 2008).

Sexton et al. (2009), also cited a report by Fingerman and Torn (2008), that claimed, by some estimates, the water consumed by feedstock crops through evapotranspiration, could by 2110 meet or exceed the total water used for evapotranspiration by all global croplands in 2002. Chemical contamination could also be an emergent issue. As prices for agricultural products rise due to biomass demand and production, farmers will find it worthwhile to add more chemicals to their crops. Increased chemical usage would likely result in increased pollution of water resources from farm runoff and groundwater percolation (Figure 28) (Sexton et al. 2009). Additionally, the water used is often derived from aquifers that may not continue to provide water indefinitely (Patzek et al. 2005).

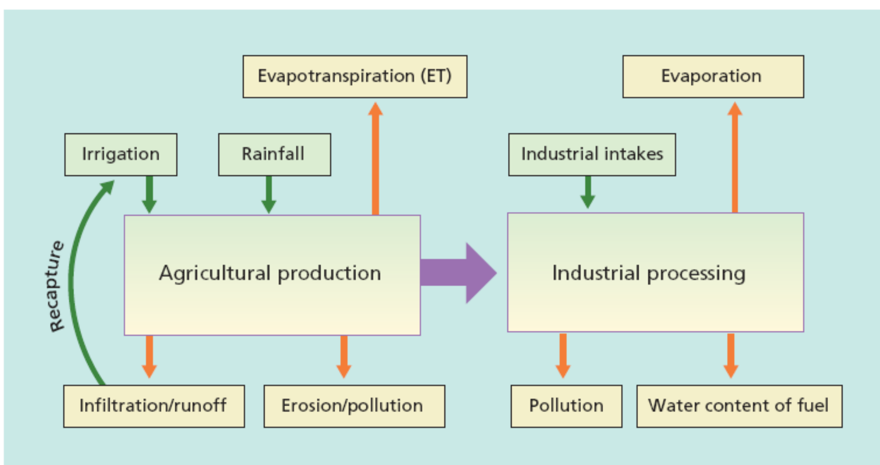


Figure 28. Water use in biofuel production (Sexton et al. 2009).

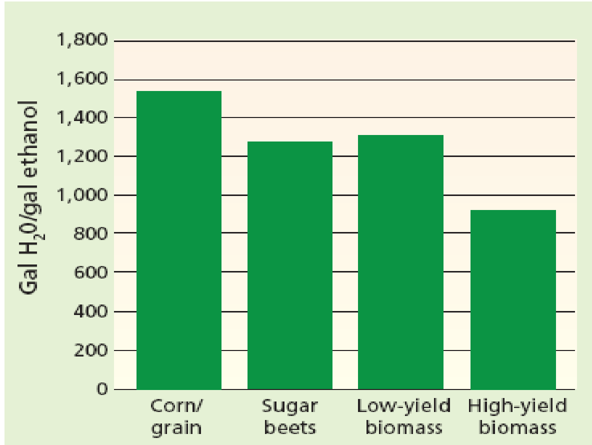


Figure 29. Water embedded in biofuel for four feedstocks. High-yield biomass = second-generation biofuels (Sexton et al. 2009).

In a case study, de Fraiture et al. (2008), noted that China and India, two of the world's largest agricultural producers and consumers, already are severely limited in water availability. However, both countries have initiated programs to increase biofuel production (de Fraiture et al. 2008). Due to water limitations, China has implemented a costly project to bring water from the south to north by diverting water from the Yangtze River to the Yellow River basin. India is considering a similar multibillion dollar project that would create inter-basin water transfers (de Fraiture et al. 2008).

From these considerations, it is clear that adoption of bioenergy on a large scale should only be attempted in conjunction with a full understanding of the bioenergy system, how it integrates with other industrial sectors, and how it impacts on the environment. Factors to consider in the energy life cycle analysis include: farming equipment, cultivation practices (tillage increases carbon loss), inputs such as fertilizer, pesticides, fungicides, and herbicides, water use, harvesting, and transportation of feedstock and biofuel. Thus, large scale bioenergy production will be a large perturbation on many linked systems, and will need a full systems approach to be properly evaluated for benefits and for costs.

4.3 Biofuel Case Studies

4.3.1 Sugarcane in Brazil

Ethanol production in Brazil and biodiesel production in Malaysia illuminate the issues associated with land clearing for feedstock agriculture.

Presently, Brazil is by far the largest sugar cane producer in the world where cane is used to produce sugar, falernum (sugary syrup added to drinks), rum, cachaca (Brazilian alcoholic beverage), and ethanol. The bagasse (remains of crushed sugar cane) and crop residue may be used to provide heat energy in the mill and electricity to the consumer electricity grid.

Marris (2006), reported on a study conducted by Isaias de Carvalho Macedo at the University of Campinas in Brazil. His study considered all the agricultural and processing inputs of sugar cane ethanol production. Macedo and his colleagues estimated that the whole well-to-wheels process cost 250,000 kilojoules per tonne of cane. Each tonne of cane would then produce roughly two million kilojoules of ethanol and surplus energy from bagasse. This equals roughly an eight fold return. Additionally, the analysis suggested that one ton of cane used as ethanol represents a CO_2 emissions net avoidance of 220.5 kilograms when compared to gasoline of the same energy content. Macedo extrapolated that

Brazilian ethanol use reduces GHG emissions by 25.8 million tons of CO_2 equivalent per year. The US Department of Energy reported that Brazil's total CO_2 emissions from fossil fuels are 92 million tons a year. Thus, 25.8 million represent a significant emission reduction. Brazilian sugar cane ethanol is also presently the cheapest to produce at 25 cents per liter. Marris (2006), also reported that annual yield was 5,300 – 6,500 liters/hectare with a green house gas savings of 87- 96% when compared to gasoline. Fulton et al. (2004), performed an analysis of the energy balance of sugar cane to ethanol in Brazil that showed the process of converting sugar cane to ethanol has improved substantially in recent years.

Table 13 analyzes data collected in studies by Macedo. The table includes all energy expended from crop production (including fertilizer production), transport, conversion to ethanol, and energy spent on equipment construction and conversion plants. The table does not include renewable energy expended, it only shows fossil energy expended. The net energy balance was found by dividing energy output by fossil energy input. It was determined to be approximately 8 on average and 10 at best. Therefore, for every unit of ethanol produced, about 0.1 units of fossil energy were required. In comparison, Fulton et al (2004), indicated 0.6 to 0.8 units of fossil energy are required to produce one unit of grain ethanol in the U.S. or Europe. The Brazilian climate reduces the need for large crop inputs due to the regions natural rainfall, intense sunlight, and productive soil.

Table 13. Energy balance of sugar cane to ethanol in Brazil (Fulton et al. 2004).

	Energy Requirement (MJ/tonne of processed cane)	
	Average	**Best values**
Sugar cane production	**202**	**192**
Agricultural operations	38	38
Cane transportation	43	36
Fertilizers	66	63
Lime, herbicides, etc.	19	19
Seeds	6	6
Equipment	29	29
Ethanol Production	**49**	**40**
Electricity	0	0
Chemicals and Lubricants	6	6
Buildings	12	9
Equipment	31	24
Total energy input	**251**	**232**
Energy output	**2089**	**2367**
Ethanol	1921	2051
Bagasse surplus	169	316
Net energy balance (out/in)	**8.3**	**10.2**

Additionally, due to excess production of bagasse energy, the plant's conversion process energy derived from fossil fuels can be reduced to zero or nearly zero. The study also noted, that 2002 annual sugar cane harvest yield was about 68.7 tonnes per hectare. That is roughly 6,200 liters per hectare per year. Fulton et al (2004), estimated that this value will likely become the average productivity over the next 5 to 10 years. Finally, recent regulations banned the burning of dry residual biomass left in the field. In the future the residual biomass will be added to the bagasse used for energy production.

As attractive as the ethanol fuel industry from sugarcane has been, there are concerns. The greatest concern is fear that along with its expansion natural forests will be converted to agricultural land, either directly through conversion to sugarcane fields or by displacing food agriculture and ranching to untouched landscapes, like the Brazilian Cerrado (grasslands). This would lead to large scale biodiversity loss and significant releases of stored carbon. However, the Brazilian pro-sugarcane ethanol industry argues that Brazil is large enough to accommodate sugar cane expansion without displacing food agriculture or coming anywhere near the rainforest. They argue the limiting factor will be capital rather than land (Marris 2006).

4.3.2 Palm Oil in Malaysia

Palm oil is an edible vegetable oil and another common biodiesel feedstock derived from the fruit of the oil palm. The oil palm is a tree found in humid tropical environments such as Malaysia, with an annual rainfall of 1800 to 5000 mm evenly distributed throughout the year. Marris (2006), estimated that the oil palm can produce an annual biofuel yield of 5,000-6,000 liters/hectare. The tree is slow to mature and takes roughly three years before it produces fruit but continues to be a viable producer for approximately 25 years. The fruit resembles avocados and grows in bunches, which are typically harvested by hand. Trees generally are planted at a density of 150 trees/hectare. The DOE (2006), reported that, once mature, oil palms can produce up to 10.6 metric tonnes of oil per hectare annually. However, the average is approximately half this value.

Palm oil is Malaysia's largest agricultural product, and is now the top selling vegetable oil in the world (Stone 2007). Malaysia presently is the largest producer of palm oil with about 13.4 billion pounds of mesocarp oil and 3.5 billion pounds of kernel oil produced from about 3.8 million hectares of land (DOE 2006). Palm oil is converted to biodiesel in a relatively straight forward process. Thus, the industry has and is expected to expand significantly.

However, expansion has come at a cost. Widespread reports claim that tropical forests have been and continue to be cleared for palm oil plantations. NGOs report that not only is critical habitat for numerous species of birds, mammals, and bats (Stone 2007) being destroyed, but also deforestation for biofuel monoculture releases carbon contributing to global warming (Righelato and Spracklen 2007). Additionally, the UN Development Programme recently reported that logging and forest clearing is endangering the way of life for local indigenous populations.

4.4 Second Generation Biofuels

Due to the significant issues associated with first generation biofuels, greater focus and political pressure has emerged to commercially develop second generation biofuels. In addition, without subsidies first generation biofuels are not cost competitive with petroleum. First generation issues are significant and attracted the attention of several of the action arenas directly or indirectly, but for the action arenas in this study they were just another set of issues. For the US Federal Government, they sat alongside of rural incomes, and agribusiness priorities in the decision making process. With the UNFCCC, fuel versus food, land use change, and the actual energy and emissions concerns were of interest. However, the process of reaching international agreement was not driven substantially by these first generation considerations for biofuels. They were second tier issues. Nevertheless, it was important that Congress, in the Energy Act 2007, mandated that new technology begin to augment corn based ethanol for biofuel. The US Federal Government, has in addition, allocated research funds to explore better fuels and the technologies to produce them. Unfortunately, in the eyes of many, the amount of funding is too small to significantly alter the current situation in the near term. As I will show in the final chapters of this thesis, the dominate biofuel in the US, is likely set to remain corn ethanol for at least another decade.

Second generation technologies promise significant improvements over first generation technologies. The non-comestible feedstocks (like hardy grasses, wood, agricultural residue, natural waste, and algae) are potentially more affordable and don’t compete directly with the food supply. Second generation biofuels are, as reported by Deurwaarder (2005), all around more earth friendly. However, the challenge for second generation technologies is to reach their promise. Thus, the dilemma with second generation lignocellulosic technology is accessing the sugars locked into strong lignin and cellulosic bonds. Present methods of release of fermentable sugars include enzymes, chemical hydrolysis (acid treatment), steam heating, and other pre-treatments. After the sugars are freed they can be fermented and processed the same as first generation technology, but none of these technologies are fully satisfactory. In what follows, I will discuss three examples of second generation biofuel technologies; two involve new feedstocks. They are lignocellulosic and algae feedstocks. The third is a new energy molecule – butanol.

4.4.1 New Feedstocks

New feedstocks are an important direction for biofuels. Crops providing most present day feedstock have been optimized for producing feed and food grains and oils on quality farmland, not for producing fuel on marginal land. Little has been done to optimize these feedstocks for fuel production, and of course, food crops may not even be the best for producing fuels. Many believe that there is great opportunity to optimize for both new feedstocks and new fuel molecules. This is almost certainly true for lignocellulosic technology which when fully developed may use agricultural waste products, but more likely will use grasses and woody plants designed specifically to be converted to fuel. Oil yielding plants are likely to go the same way.

Another line of exploration is conversion technology and the energy molecule itself. Bioethanol requires sugars or starches for traditional production, and biodiesel requires triglycerides, but much of biomass comes in the form of lignocelluloses, or in the case of microorganisms, carbohydrates and proteins. Agricultural waste such as corn stover, grasses, and woody plants are all rich in cellulose. Today this biomass can only be used for fuels by direct combustion or by anaerobic digestion to biogas. Much research is now directed toward releasing cellulose and converting it to sugars that can be used for bioethanol or other energy molecules (Cardona and Sanchez 2007, Solomon et al. 2007).

Success in conversion technology research opens up the possibility of using perennial grasses, such as switch grass and miscanthus. The DOE (2006), noted that these crops are more agriculturally efficient requiring fewer inputs and add greater benefit to the land ecologically. Less fertilizer is required for these perennial crops. This is partially due to perennial root systems which are long lived and form interactions with root symbiants which facilitate acquisition of mineral nutrients. By requiring smaller amounts of fertilizer, run off for perennials is much lower than for corn and other grain crops. Additionally, perennials better retain mineral nutrients, improve soil quality and decrease soil erosion due to the soil stabilizing capability of the roots. Perennials also have higher annual solar energy conversion efficiency than annuals. DOE (2006), reported on studies by S. Long at the University of Illinois, perennials were found to establish a photosynthetically active canopy more quickly in the spring that may also persist longer into the fall. The study noted that perennials in temperate zones may have substantially greater total biomass yields per unit land area than annuals. Reduced tillage, once the crop is established, may also increase soil carbon levels thus sequestering atmospheric carbon into the soil.

Further lines of exploration that may create a more advantageous outcome would be to identify ideal feedstock plants. Plants used for food have been designed over many years, millennia in some cases, for food – not fuel. An "ideal" plant may have some of the characteristics in Table 14 below.

Table 14. Attributes of an "Ideal" biomass crop. (DOE 2006)

The "Ideal" Biomass Crop?	Corn	Short-Rotation Coppice*	Perennial Grass
C4 photosynthesis	*		*
Long canopy duration		*	*
Recycles nutrients to roots			*
Clean burning			*
Low input		*	*
Sterile (noninvasive)	N/A	(*)	M.g.**
Winter standing		*	*
Easily removed	*		*
High water-use efficiency			*
No known pests or diseases			M.g.
Uses existing farm equipment	*		*

* Coppice is a grove of densely growing small trees pruned to encourage growth; ** *Miscanthus giganteus.*

Perennial grasses, such as switch grass and miscanthus, are considered advantageous for a number of reasons. First, they have all the qualities of perennials noted above. Shubert (2006) and Sanderson (2006), reported that miscanthus (elephant grass) can create an annual yield of 7,300 litres/ha of biofuel and a GHG savings in the range of 37% to 73% (most were in the range of 65% - 70%) versus gasoline. They also indicated that switchgrass can create an annual yield of 3,100 to 7,600 litres/ha of biofuel and, like miscanthus, a GHG savings in the range of 37% to 73% (most were in the range of 65% - 70%) versus gasoline. David Tilman of the University of Minnesota (Tilman 2006) encourages planting a mixture of prairie grasses. Based on his experimental plots, low input and high diversity grasses are more resistant to drought and pests than farmed monocultures, and on average yield 2.7 times as much biomass than even the highly regarded switchgrass.

Rosillo-Calle (2007), described some of the advantageous qualities of switchgrass. It is a C4 grass, a good source of energy, excellent cover for wildlife, and prevents soil erosion. Switchgrass is long lived and can produce high yields on marginal soils at low starting costs. It also is a low input crop, cold tolerant, and can adapt to a wide variety a agroecosystems. The DOE (2006), reported on a switchgrass study done by K. Vogel of the University of Nebraska involving a 5 year old switchgrass field in Northeast South Dakota in 2005. They noted that each 1200 lb bale could create 48 gallons of ethanol at a conversion rate of 80 gallons per ton. The field had a potential of 5 to 6 tons per acre or 400 to 500 gallons of ethanol per acre, as this cultivar was bred as pasture grass. Experimentally, 10 tons per acre have been achieved, with processing goals at 100 gallons per ton of biomass, or an ethanol yield of 1000 gallons per acre.

4.4.2 Algae and Other Microorganisms

There is much interest in and promise for algae and bacteria. These photosynthetic microorganisms are promising because they can be engineered to produce very high levels of lipid (precursor to biofuel). They can, in theory, consume post combustion carbon dioxide from power plants and clean waste water from sewage plants or contaminated waters with high concentrations of nitrate or phosphate. With suitable reactor designs they could in principle even grow on desert land. Using microorganisms for fuel production is not a new idea. The challenge has been the reactor design which needs to be inexpensive and rugged to withstand difficult environments. Low-cost, race-way ponds have experienced difficulties with contamination by organisms with poor fuel production characteristics and water loss through evaporation. In contrast, standard bioreactors which can maintain relatively pure cultures can be very expensive.

Photosynthetic microorganisms are promising because they can be engineered to produce very high levels of lipid (precursor to biodiesel). They can in theory, consume post combustion carbon dioxide from power plants and waste water from sewage plants or contaminated waters with high concentrations of nitrate or phosphate. Due to algae's rapid growth rates, which exceed plant-based feedstock, it may become the most viable crop to address the world's motor fuel needs. Ledford (2006), reported that annual algae yields range from 10,000 to 12,000 litres per hectare, and create significant GHG savings. Algae out-produce all other biofuel feedstocks per hectare. In comparison Marris (2006) reported that palm oil produces 5,000 – 6,000 litres of biodiesel/hectare, sugar cane produces 5,300 to 6,500 litres of ethanol/hectare, corn ears produce 3,100 to 3,900 litres of ethanol/hectare, and Miscanthus, given cellulosic technology, can produce 7,300 litres of ethanol/hectare (Sanderson 2006). The lipid is also a higher energy density molecule giving an added advantage of algae over ethanol feedstock crops. See Table 15, for a comparative analysis of other biofuel feedstock crops.

Conversion of algae oil into biodiesel is the same as for oils from land crops. The greater concern is in finding algae strains with a high lipid content and a fast growth rate that is easy to harvest, and finding a cost effective bioreactor suited for cultivation. Other microorganisms such as diatoms and cyanobacteria which are capable of photosynthesis yet are smaller than 2mm in diameter, have become a focal point in research for mass production. Their appeal is due to their less complex genetic structure which makes them easier to manipulate, fast growth rate, and high oil content in some species.

Table 15. Preliminary assessment of biomass feedstocks (UN 2007).

Crop Type	Crop Requirements			
	Soil	**Water**	**Nutrients**	**Climate**
Cereal	less disruption of soil; very constant yield; humus balance is negatively influenced by annual removal of straw	_	medium	moderate
Hemp	deep soil with good water supply, pH balance between 6 and 7	some moisture the entire season	moderate, no pesticide needed	varied environmental conditions, preferably warmer climates
Jatropha	undemanding, does not require tillage	can be cultivated under both irrigated and rain-fed conditions	adapted to low fertility sites and alkaline soils, but better yield can be achieved if fertilizers are used	tropical and subtropical but also arid and semiarid
Maize	soil should be well-aerated and well-drained	efficient user of water	require high fertility and should be maintained continuously	temperate to tropic conditions
Miscanthus	good water supply, brown soils with high humus percentage, optimum pH between 5.5 and 7.5	crucial during the main growing seasons	low	adapted to warmer climates but fairly cold-tolerant
Oil Palm	good drainage; pH between 4 and 7; soil flat, rich, and deep	even distribution of rainfall between 1,800 and 5,000 throughout the year	low	tropical and subtropical climate with temperature requirement of 25-32 Celsius
Poplar	deep, moist soil, medium texture, and high flood tolerance	high; irrigation may be needed	high	artic to temperate
Potato	deep, well drained, friable, well-aerated,	high; irrigation required	high fertilizer demand	optimum temperature of 18-20 Celsius

	porous, pH between 5 and 6			
Rapeseed	mild, deep loamy, medium texture, well-drained	600 mm minimum yearly precipitation	similar to wheat	sensitive to high temperatures, grow best between 15 and 20 Celsius
Rice	needs permeable layer and good drainage	very high, grown in flooded fields	relatively high input of fertilizers, very intensive systems	constant temperatures, grow best between 15 and 20 Celsius
Sorghum	light-to-medium textured soils, well-aerated, well-drained, and relatively tolerant to short periods of water logging	shows a high degree of flexibility towards depth and frequency of water supply because of drought resistance characteristics	very high nitrogen feeding crop	optimum temperatures for high producing varieties are over 25 Celsius
Soybean	moist alluvial soils with good organic content, high water capacity, good structure, loose soil	High	optimum soil pH of 6 to 6.5	tropical, subtropical, and temperate climates
Sugarbeet	medium-to-slightly heavy texture, well-drained, tolerant to salinity	moderate, in the range of 550 to 750 mm/growing period	adequate nitrogen is required to ensure early maximum vegetative growth, high fertilizer demand	variety of temperate climates
Sugarcane	does not require a special soil type, but preferable well-aerated with a total available water content of 15% or more	high and evenly distributed through the growing season	high nitrogen and potassium needs but at maturity, the nitrogen content of the soil must be as low as possible for a good sugar recovery	tropical or subtropical climate
Sunflower	grown under rain-fed conditions on a wide range of soils	varies from 600 to 1,000 mm, depending on climate and length of total growing period	moderate	climates ranging from arid under irrigation to temperate under rain-fed conditions

Switchgrass	ranging from prairies to arid to marsh	drought-resistant and very-efficient water use	low	warm-season plant
Wheat	medium textures	High	high	temperate climates, in the subtropics with winter rainfall, in the tropics near the equator, in the highland with altitudes of more than 1,500m, and in the tropics away from the Equator where the rainy season is long and where the crop is grown as a winter crop
Willow	sandy, clay, and silt loams	substantial quantities of water	significant nutrient uptake	can tolerate very low temperatures in winter, but frost in late spring or early autumn will damage the top shoots

4.4.3 New Energy Molecule – Butanol

Biobutanol is poised as a better molecule to replace ethanol as a substitute for gasoline fuels. It can be produced from the same biomass feedstock as ethanol, and like ethanol, it can be produced fermentatively or petrochemically (Durre 2007). Cascone (2008), outlined the advantages of butanol over ethanol:

- Butanol is easily incorporated into and used in existing petroleum infrastructure, including pipeline transportation.

- Butanol avoids the need for plant restructuring and operational changes as it can be blended, at any ratio, into gasoline or diesel at existing refineries.
- Butanol does not absorb sludge or water, nor does it dissolve rust and undesirable materials in pipelines, tanks, and equipment.
- Butanol's octane values and energy density approach gasoline's. Thus, vehicle fuel economy (mpg) will not significantly degrade as seen in gasoline-ethanol blends.
- Butanol has a much lower vapor pressure than ethanol. Therefore, it will not raise the fuels Reid vapor pressure permitting the use of lower cost octane enhancers like butane (high vapor pressure) in butanol-gasoline blends in warm seasons. Reid vapor pressure is a measure of fuel volatility. The desired measure is dependent upon ambient temperature. Cold climates may result in too little volatility and an inability of the car to start. Overly hot climates can result in excess volatility, where the liquid fuel changes to a gaseous fuel, rendering a fuel pump ineffective and depriving the engine of fuel.
- The low solubility of butanol in water, and water in butanol, lessons the risk for spills to spread into groundwater.
- Butanol, like other alcohols, is largely biodegradable thereby limiting environmental impacts in the event of a spill or leak.

Cascone (2008) compared the properties of n-butanol, ethanol, and gasoline, and showed that the properties that make butanol superior to ethanol are the heating value, RVP, octane number, and water solubility (Table 16). A higher heating value, or one that is closer to gasoline, is better. Heating value relates directly to how often one would have to refill their vehicle. It is the energy per liter. Butanol has a higher heating value than ethanol, and is closer to gasoline.

Table 16. Properties of n-butanol, ethanol and gasoline (Cascone 2008).

Properties	**n - Butanol**	**Ethanol**	**Gasoline**
Specific Gravity at 60 Fahrenheit	0.814	0.794	0.720-0.775
Heating Value, MJ/L	26.9-27.0	21.1-21.7	32.2-32.9
Research Octane Number (RON)	94*	106-130*	95
Motor Octane Number (MON)	80-81*	89-103*	85
RVP of 5% and 10% - Alcohol/Gasoline Blends, psi	6.4*/6.4*	31*/20*	#
Oxygen, wt.%	21.6	34.7	<2.7
Water Solubility at 25 Celsius, %	9.1	100	<0.01

* Gasoline blend values of the alcohol octane numbers and vapor pressures; # For comparison, the summer/winter specifications for gasoline are <7.8/15 psi.

Additionally, the octane rating of n-butanol is closer to gasoline than ethanol, but lower than ethanol. The higher value for ethanol is an advantage, as it can be added to standard gasoline as an octane enhancer to reduce engine knocking, and improve energy efficiency, power and torque. The higher octane value is the result of higher oxygen content in the ethanol that makes the fuel burn cleaner..

RVP is the Reid Vapor Pressure. It is measured in pounds per square inch (psi), and is a measure of the volatility of a fuel. The lower the pressure, the lower the volatility, and consequently evaporative emissions and air pollution. Butanol has a lower RVP than ethanol, and is better than ethanol in this regard.

Water solubility is a serious issue with ethanol, as mentioned above. Solubility and the hygroscopic properties of ethanol complicate transportation and storage logistics. Ethanol is very water soluble unlike gasoline. Butanol has a very low water solubility, and is less likely to pick up impurities or to cause phase separation.

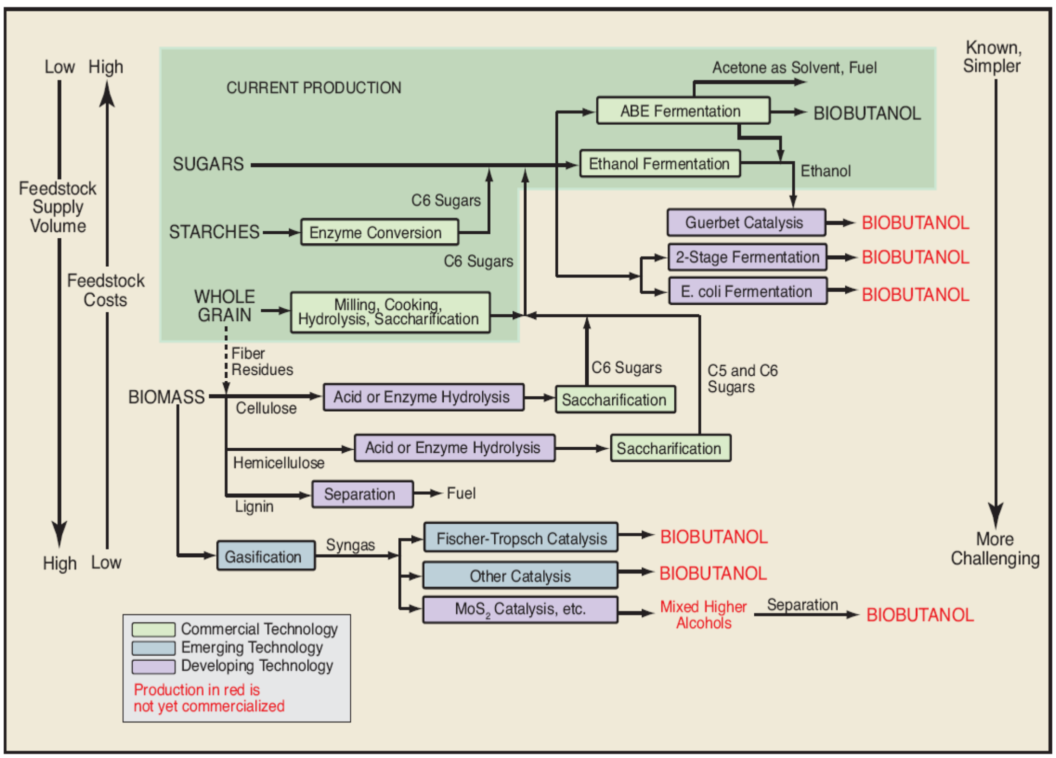


Figure 30. Process for production of biobutanol (Cascone 2008).

Biobutanol can use the same feedstocks as ethanol (cellulose, corn, wheat, sugarbeat, sorghum, cassava, and sugarcane) (Durre 2007, Cascone 2008). It is produced by a number of methods, including fermentation and thermochemical routes (Figure 30). Current production primarily utilizes acetone-butanol-ethanol (ABE) fermentation, which uses the bacterium Clostridium acetobutylicum (or Weizmann organism) (Cascone 2008). Products from this process also include H_2, acetic acid, lactic acid and propionic acid.

As I indicated at the outset of this chapter, it is well recognized by those familiar with first generation biofuels that the associated problems are significant and need to be addressed. But there are no action arenas for these issues. They become context (exogenous variables) for arenas that do drive policy. These issues are not central yet to policy making considerations. They are secondary to the larger issues like farming income, energy prices, energy security, and supply and demand, to name a few. Nevertheless, global support for research has brought many of the concerns into better focus. The hope is, that through research, crops and farming methods can be found that will require fewer inputs, make productive use of marginal lands, and not create competition with food.

Case studies presented in this chapter help illuminate real world examples of these issues. Second generation biofuels would avoid the difficulties described in this chapter. To the extent these new biofuels are considered by action arenas, they are viewed favorably. For example, the US government is supporting a variety of research for cellulosic technologies as well as algae and other nonfood oil products. From a policy perspective, it is important that this research is supported especially by the US Federal Government as the technologies are too early stage for businesses to seriously consider. Without policy support, second generation fuels will not happen in a meaningful time frame.

CHAPTER 5

FUTURE OF BIOFUELS AND ENERGY SUSTAINABILITY IN THE UNITED STATES

5.1 Introduction

In previous chapter I have shown how the IAD framework can be used to understand the policy history of biofuels and especially corn based bioethanol. The shape of the biofuel industry in the United States is explained by actions within five action arenas. I will now discuss how this same framework can be used to reflect on the future. Specifically, I will address my third question: what is the future for biofuels in the United States, and how is it related to energy sustainability?

Thus far, the action arenas do not coordinate their efforts. Outcomes from one serve as inputs to the others, but each has its own primary drivers that are not explicitly about biofuels. In the absence of coordination, the future of biofuels will depend on a suite of factors, some of which are important to biofuels, and some that are not. This being the situation, I consider two limiting cases for how the future of biofuels might unfold, a business-as-usual scenario and an approach focused on sustainable biofuel use.

In the business-as-usual scenario, ones assumes that the fairly loose connection between action arenas, seen thus far, continues into the future. Given there is no trajectory change in the action arenas, one might expect that the past is a reasonable guide for the future. This business-as-usual case is similar to the assumptions made by the EIA while producing energy outlooks. The most recent projections provided by the EIA in the Energy Outlook for 2009 and 2010 will be explored below as a business as usual projection.

5.2 U.S. Biofuel Projections

Every year the EIA Annual Energy Outlook prepares projections of energy supply and demand for the United States. These projections typically have a 25 year or more time horizon. The EIA created projections for total bioenergy, ethanol, biodiesel, wood and other biomass, and biogenic municipal waste. Biomass consumption increases by 4.4% per year on average from 2007 to 2030 and makes up 22% of total marketed renewable energy consumption in 2030, compared with 10% in 2007 (EIA 2009a). Figure 31, illustrates the rise in total biofuel percentage in the total energy mix. In 2006, one sees the total biofuel percentage in US total energy consumption, beginning at 0.8% and reaching 3.6 % by 2030. In energy units this approximately is 0.8 quadrillion Btu of biofuels per year in 2006 out of a total US energy consumption of 100 quadrillion Btu. In 2030, those values increase to 4 quadrillion Btu of biofuels and 114 quadrillion Btu total energy consumption.

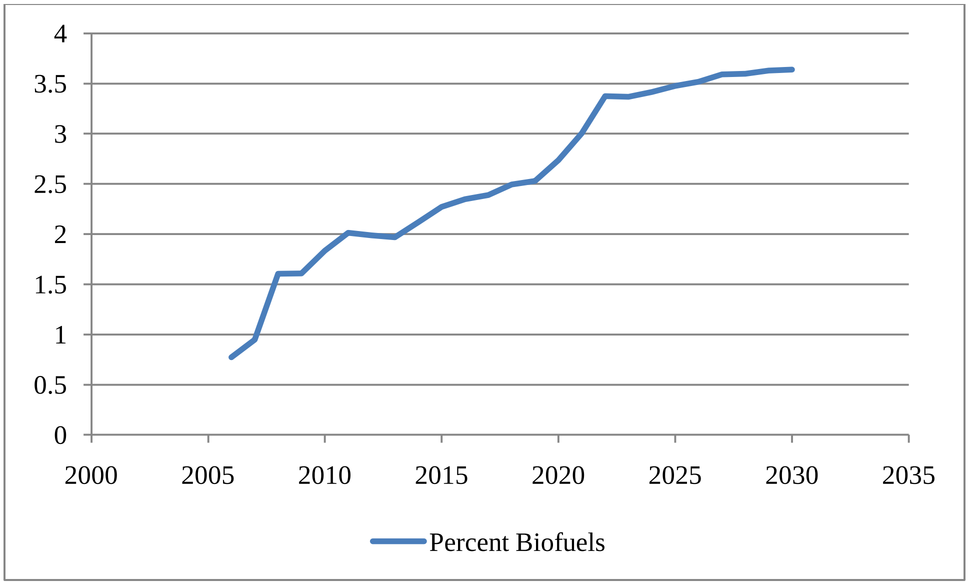


Figure 31. Projections for percent biofuels in total U.S. energy mix. Original units are in quadrillion Btu per year. Includes data for heat, co-products, and ethanol consumption from motor gasoline and E85 (adapted from (EIA 2009a).

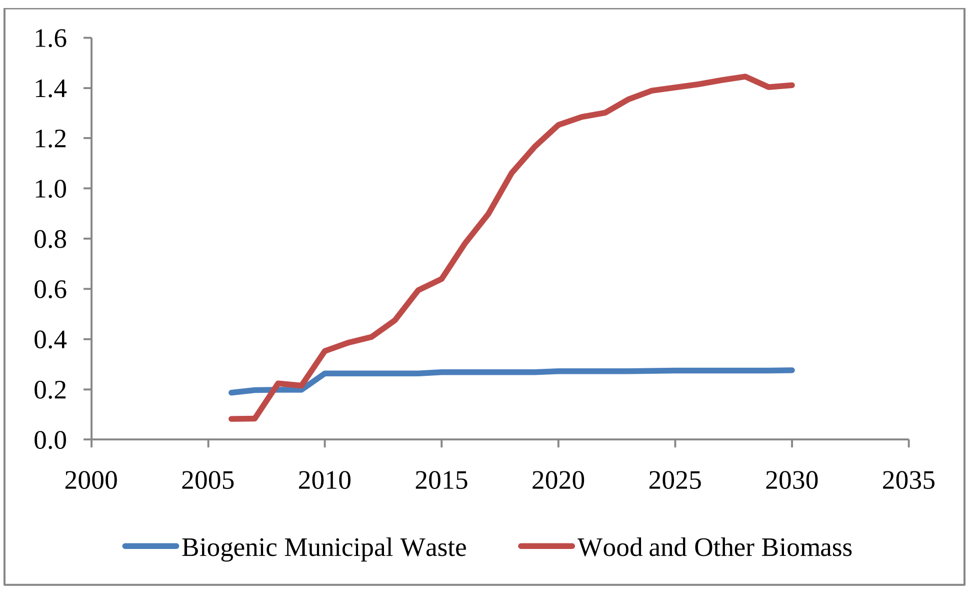


Figure 32. Projections for renewable energy generation from biogenic municipal waste and wood and other biomass. Units are in quadrillion Btu (adapted from (EIA 2009a).

Figure 32. shows the amount of energy derived from biogenic municipal waste and wood and other biomass. Wood and other biomass, are the primary source of energy production. Biogenic municipal waste begins at 0.2 quadrillion Btu in 2006 and flat lines at approximately 0.3 quadrillion Btu in 2015. Wood and other biomass begin as a lesser source of energy in 2006 at 0.08 quadrillion Btu but by 2010 it surpasses biogenic municipal waste with 0.35 quadrillion Btu versus 0.26 quadrillion Btu for municipal solid waste. EIA projections have wood and other biomass peak at 1.5 quadrillion Btu in 2028 and fall slightly to 1.4 quadrillion Btu in 2029 and stay essentially flat to 2030.

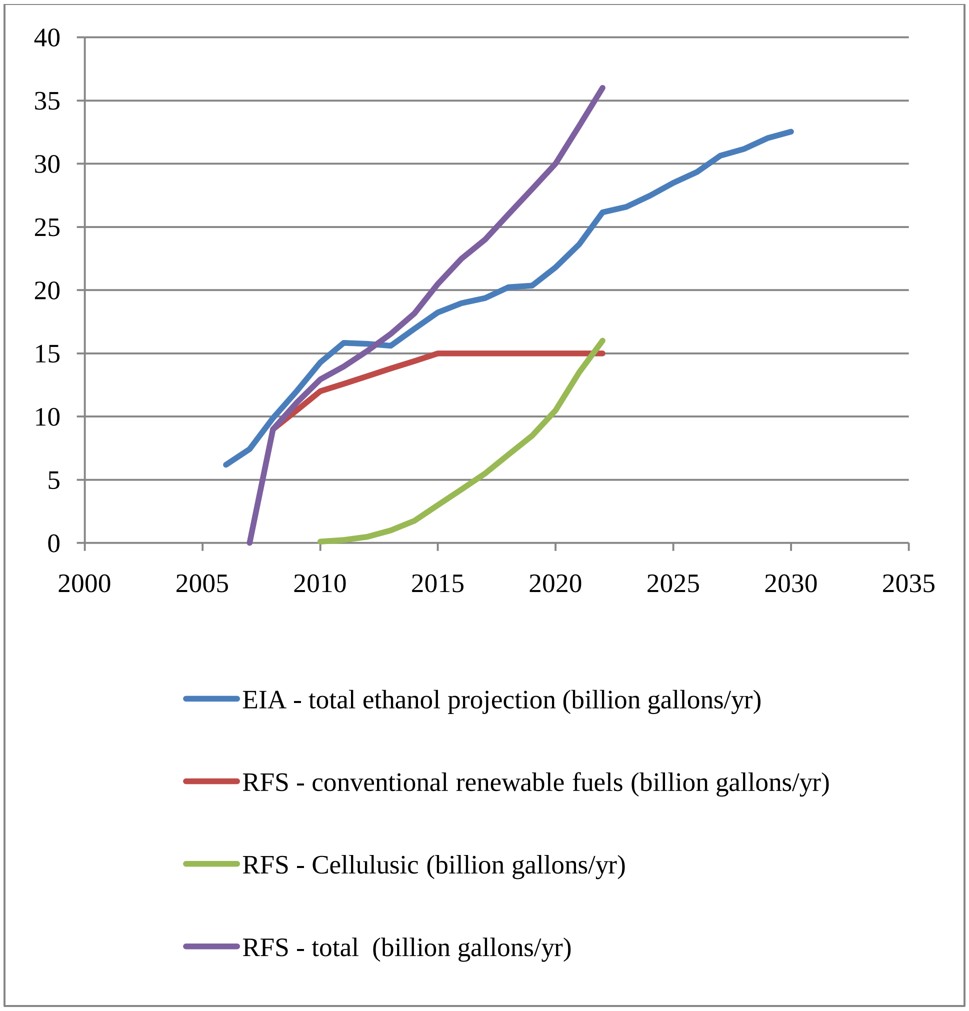


Figure 33. Projections of total ethanol use versus RFS mandates (adapted from (EIA 2009a).

In 2006, the EIA's projection for total ethanol production began at 6.20 billion gallons/year. In 2008 the Renewable Fuel Standard (RFS) for conventional ethanol (seen in RFS total ethanol – Figure 33) required a volume of 9.0 billion gallons/year, which was below the actual ethanol production at that time of 9.87 billion gallons/year (EIA 2009a). In 2010, the RFS also began mandating a volume of 0.1 billion gallons/year of cellulosic ethanol. The RFS is presently not extended beyond 2022. The 2022 RFS for conventional ethanol is 15 billion gallons/year, RFS for cellulosic ethanol is 16 billion gallons/year and the RFS total is 36 billion gallons/year. However, the EIA projections for 2022 for actual ethanol production are about 26 billion gallons/year. However, EIA projections continue to 2030 where production reaches 32.5 billion gallons/year.

Growth drivers affecting the future of biofuel use include, the Energy Independence and Security Act (EISA) of 2007, RFS mandates, production tax credits, and future lines of research.

The Renewable Fuel Standards (RFS) was first established in the Energy Policy Act of 2005. It was later expanded in the Energy Independence and Security Act of 2007. EISA 2007, was signed into law on December 19, 2007 and took effect in January 1, 2009. Under the EISA, the Renewable Fuel Standards (RFS) created greater volumetric mandates for biofuel production which requires 7.5 billion gallons by 2012 and 36 billion gallons by 2022 (Table 17). The RFS also required a minimum quantity to be derived from advanced biofuels, cellulosic biofuels and biodiesel. The table that follows summarizes the 2007 RFS mandates:

Table 17. EISA renewable fuels standards (110th U.S. Congress 2007).

Year	**Biofuel production (In billions of gallons)**					
	Conventional biofuel	Advanced biofuel	Cellulosic biofuel	Biomass based diesel	Undifferentiated advanced biofuel	Total RFS
2008	9.00	-	-	-		9.00
2009	10.50	0.60	-	0.50	0.10	11.10
2010	12.00	0.95	0.10	0.65	0.20	12.95
2011	12.60	1.35	0.25	0.80	0.30	13.95
2012	13.20	2.00	0.50	1.00	0.50	15.20
2013	13.80	2.75	1.00	*	1.75	16.55
2014	14.40	3.75	1.75	*	2.00	18.15
2015	15.00	5.50	3.00	*	2.50	20.50
2016	15.00	7.25	4.25	*	3.00	22.25
2017	15.00	9.00	5.50	*	3.50	24.00
2018	15.00	11.00	7.00	*	4.00	26.00
2019	15.00	13.00	8.50	*	4.50	28.00
2020	15.00	15.00	10.50	*	4.50	30.00
2021	15.00	18.00	13.50	*	4.50	33.00
2022	15.00	21.00	16.00	*	5.00	36.00

* At least 1.00 (specific amount to be determined by the administrator)

The Energy Independence and Security Act defines conventional biofuels as ethanol derived from corn starch that meets at least a 20% reduction in lifecycle GHG emissions compared to baseline lifecycle GHG emissions. Advanced biofuels are renewable fuels not derived from corn starch. This is a large category that includes ethanol derived from cellulose or lignin, non-corn derived sugar and starch, and waste material; biomass-based diesel; biogas derived from renewable biomass; butanol and other alcohols derived from renewable biomass; and fuels derived from cellulosic biomass. To be categorized as an advanced biofuel, the production of the fuel must achieve lifecycle greenhouse gas emissions of at least 50% below baseline emissions. Cellulosic ethanol is derived from cellulose and lignin harvested from renewable biomass crops. It must achieve at least a 60% reduction in lifecycle GHG emissions compared to baseline lifecycle GHG emissions. Biomass-based biodiesel, (defined by the EPA) is produced from nonpetroleum renewable resources and meets the registration requirements for fuels and fuel additives. It has at least a 50% reduction in lifecycle GHG emissions compared to baseline emissions. Undifferentiated advanced biofuels include cellulosic biofuels, biomass-based diesel, and co-processed renewable diesel. It does not include corn ethanol, and it has at least a 50% reduction in lifecycle GHG emissions compared to baseline lifecycle GHG emissions. The term baseline lifecycle greenhouse gas emissions refers to the average lifecycle GHG emissions for gasoline or diesel used in transport in 2005.

EISA 2007, promotes research and development for biofuels. It promotes research to expand biodiesel and biogas use as motor fuels; authorizes grants for R&D and commercial applications for cellulosic biofuel technology; promotes the conversion of corn-based ethanol plants to the production of cellulosic biofuels; explores the feasibility of algae for biofuel production; and promotes university based biofuel R&D.

Production tax credits (PTC) provided the support for companies to invest in renewable fuels by permitting them to write off renewable investment against other investments they made. In the American Recovery and Reinvestment Act of 2009, President Obama extended the use of PTC. The use of this policy tool has been instrumental in the growth of the renewable energy sector. Companies that generate closed-loop bioenergy (using dedicated energy crops) can receive a PTC of 2.1 cents per kilowatt-hour benefit in the first ten years of the renewable facilities operation. Companies using “open loop” biomass, like farm and forest wastes, can receive a PTC of 1 cent per kilowatt-hour.

In the absence of new policy, EIA Annual Energy Outlook 2009 has projected U.S. energy related carbon dioxide emissions will grow 8.7% by 2030. U.S. Carbon dioxide emissions for 2008 were 5.8 billion metric tons and by 2030 emissions are projected to reach 6.3 billion metric tons. This is an annual growth rate of 0.3%. Carbon dioxide dominates in the percentage of GHG emissions, but EIA expects other greenhouse gases to follow the same pattern. A 0.3% annual GHG emissions growth rate is a decline from 20 years ago, when the rate of increase was 0.7%. However, 0.3% falls far short of Obama’s pledge to reduce GHG to roughly 17% below 2005 levels by 2020.

The EIA’s early release of the Annual Energy Outlook 2010, projects petroleum demand will remain nearly constant and reliance on imported liquid fuels will decrease significantly over the next 25 years. Biofuels are projected to make up for this increase demand in liquid fuels. However, the report also projects that biofuels will not reach the 2022 Renewable Fuel Standard of 36 billion gallons. Flex-fuel vehicles and electric vehicles are projected to dominate the sales of cars and light duty trucks by 2035, thereby reaching an average light duty fuel efficiency of 40 miles per gallon. These and other energy efficiency measures and structural changes in the U.S. economy, leads the EIA to presume that this will keep the overall energy growth low ,and energy consumption growth at only 14% in 27 years. However, it is important to note that projections are based on the existing state of affairs, and excludes future policy changes like cap and trade and technology improvements that are not commercially viable today, but could improve in the future. Richard Newell, the EIA Administrator said recently that the EIA's "projections show that existing policies that stress energy efficiency and alternative fuels, together with higher energy prices, curb energy consumption growth and shift the energy mix toward renewable fuels. Assuming no new policies [are legislated], fossil fuels would still provide about 78% of all the energy used in 2035." Presently, fossil fuels make up around 84% of America's energy (EIA 2009a).

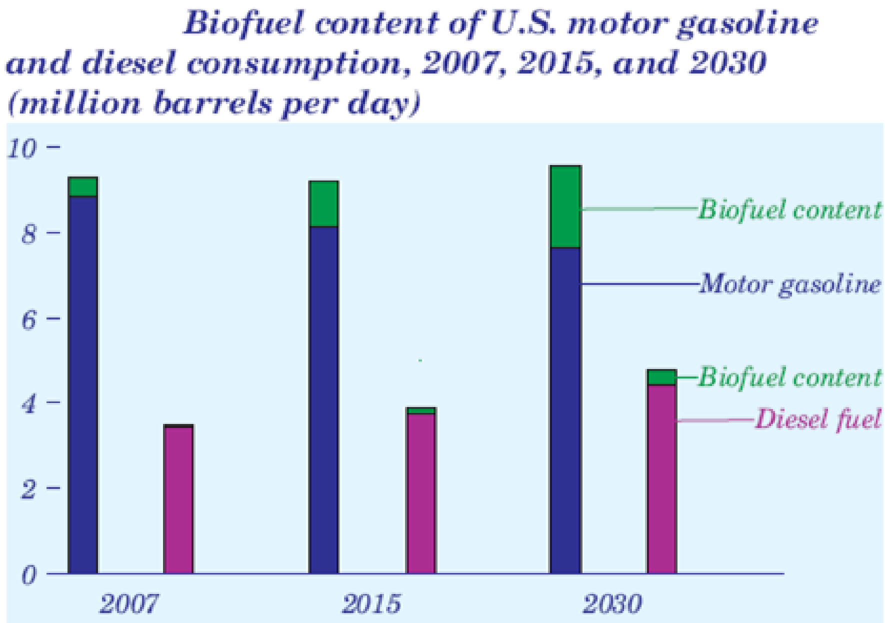


Figure 34. Biofuels displace conventional fuels in the transportation mix (EIA 2009a).

Figure 34 shows that while total energy demand for gasoline type fuels will slightly increase to 2030, biofuels will make up for the new energy demand, and will also displace the usage of motor gasoline from 2007 to 2030. The demand for diesel fuels is also projected to increase to 2030. However, biodiesel content, while increasing, will not make up for this increase in overall diesel demand. Conventional diesel fuel use will increase from 2007 to 2030.

Sustainable biofuels were developed to address several issues, high and volatile petroleum prices, secure access to energy supply, reduce dependence on imports, economic revitalization in rural areas, climate change, and air pollution. They have the potential to contribute to such a future, but as the EIA projections show, the future or biofuels remains uncertain.

Thus, as we see in the case above, essentially business as usual prevails within the IAD. In this future, the details regarding the role for biofuels are uncertain, but in any event are small. However, if action arenas began to be more tightly integrated by a greater alignment of interests, the future may look very different. Policy would change significantly, if for example, a climate treaty could be agreed upon in the UNFCCC framework, and if the DOHA round within the WTO was successfully completed, requiring the US to reduce agriculture subsidies. New international policy would create significant pressure on the US Federal Government, which may result in the more rapid deployment of low carbon energy technologies. The combined change in these three action arenas will undoubtedly influence, the other two arenas, the grain and oil markets. In these futures, you could see pressures on more rapid adoption of newer biofuels, through more price supports, research, taxation on current energy supply, or demand management to mention a few. Predictions about the future of biofuels are still difficult to make, but in the case that action arenas do begin to align, it is likely to be in favor of more rapid deployment. Given this alignment, safe sustainable guidelines are necessary to ensure the successful deployment of biofuel technology. In the next section, I consider how biofuels can be made more sustainable.

5.2 Making Biofuels Sustainable

Sustainable biofuels were developed to address several issues; high and volatile petroleum prices, secure access to energy supply, dependence on energy imports, economic revitalization in rural areas, climate change, and air pollution. Much work has been devoted to setting conditions for sustainable biofuels. The DOE (2006), suggested the need for a thorough understanding of the biomass conversion pathway and its long term harvesting impacts on soil fertility. They noted the importance of soil fertility and soil microbial communities. The DOE indicated that the vital nutrients present in process residues must be returned to the soil. Additionally, knowledge on the composition and population dynamics of soil microbial communities must be implemented in order to ensure the microbes contribute to sustainable soil productivity.

The World Business Council for Sustainable Development (2006) emphasized that biomass consumed for energy should be regenerated by reforestation or replanting. In the absence of this practice the biomass produced would contribute to unsustainable forestry, or agricultural practices, or lead to the permanent conversion of forest and plant areas. Under these circumstances the lack of biomass replacement would break the natural carbon cycle and would be just another unsustainable process for accessing energy. Fritsche et al. (2006), also indicated the importance of clarifying land ownership, ensuring a share of proceeds to the workers and local community, and avoiding negative human health impacts.

Palmujoki (2009), updated the status of sustainable biofuels production discussing international attempts, thus far, to regulate the production and trade of biofuels by establishing criteria, indicators, and certification schemes. The criteria and indicators were developed to clarify and establish the principles of sustainable biofuel development and create international norms. Palmujoki (2009), identified the many participant groups and the roles they play in the global public domain (Table 18). The abbreviated names all have their own standards that may then be used in certification schemes (van Dam et al. 2008).

Table 18. Origins, sponsors, and members in C&I schemes (Palmujoki 2009).

Origins, sponsors, and members in C & I schemes[1]			
	Initiated by:	Global origin	Members
FSC[2]	Ns	North-South	I, Ns, Ps,R
ITTO[3]	Gs	South	Gs
Pan European[4]	Gs	North/regional	Gs
Basel criteria[5]	N/R	North	I, Ns, R
Cramer criteria[6]	G	North/national	G, Ns
FBOMS[7]	N	South/national	N
RSB[8]	N	North-South	G,I,IO, Ns, Ps, R
RSPO[9]	N	North-South	I, Ns,Ps, R
RFTO[10]	G	North/national	G, Ns
SBA[11]	Ns	North/national	G, Ns, Ps, I, R
WWF-Biomass[12]	N	North	N

[1]Abbreviations: G, government; I, industry; IO, international organization; N, NGO; P, producers; R, retailers; [2]FSC International Standard (1996); [3]ITTO (1998); [4]Improved Pan-European Indicators for Sustainable Forest Management (2003); [5]The Basel Criteria for Responsible Soy Production (2004); [6]Cramer Commission (2006); [7]FBOMS; [8]RSB - Roundtable of Sustainable Biofuel (2008); [9]RSPO - Roundtable on Sustainable Palm Oil (2007); [10]RFTO - The Renewable Transport Fuel Obligation (2006); [11]SBA - Sustainable Biodiesel Alliance (2008); and [12]WWF - Biomass (2007).

Van Dam et al. (2008)'s review of initiatives on biomass recognized a number of different areas requiring further criteria and indicators (Figure 35) and identified five stakeholders and their interests in certification (Table 19).

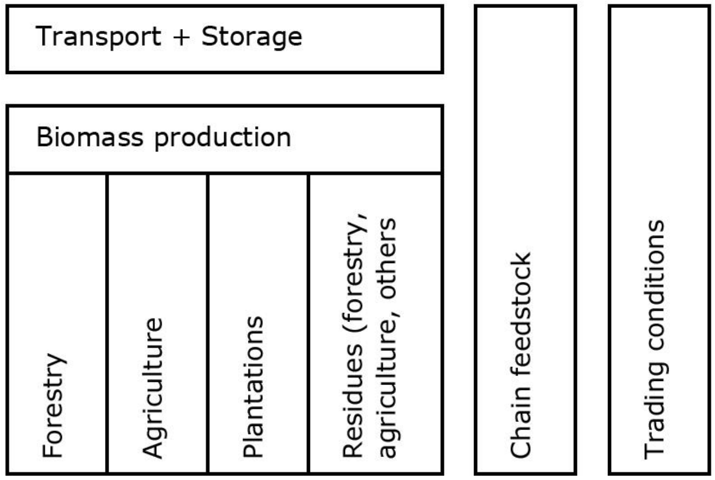


Figure 35. Areas requiring criteria and indicator development (van Dam et al. 2008).

Table 19. Stakeholder groups and interests in certification (van Dam et al. 2008).

Stakeholders	**Some interests for biomass certification**
National governments and transnational organizations	Policy instrument to promote sustainable management and sustainable consumption pattern;, provides information for policy making, The EU, one of the more powerful players for establishing international standards has a special role in this
Intergovernmental Organizations	The UN, FAO, and UNEP in particular, play an important (potential) role as a neutral forum for negotiations between all kinds of stakeholders (particularly countries)
Companies (producers, trade, industry)	Instrument for environmental marketing, risk management and market access, tool for controlling origin and quality of raw materials, products or services, provides information for optimization of production processes, allows for product differentiation
NGOs	Provides information on the impacts of products, provides information whether the product meets quality or technical standards, instrument to promote sustainable management
International bodies and initiatives	Instrument to promote sustainable management and sustainable consumption pattern, information for policy consultancy and collaboration

One amongst numerous, comprehensive efforts indicative of sustainable biofuel standards was lead by The Roundtable of Sustainable Biofuels. They describe themselves as an international initiative coordinated by the Energy Center at the Swiss Federal Institute of Technology in Lausanne. They join farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies concerned with ensuring the sustainable production and processing of biofuels. The RSB, and their union of associated parties, developed a set of working principles to facilitate sustainable biofuel policy and production. Sixteen principles were drafted under five categories, national law, greenhouse gas, environmental impacts, social impacts, and traceability (Roundtable on Sustainable Biofuels 2007):

I. National Law

1. Local and national laws, labor laws, and land and water rights must govern biomass production. Where this legislation is non-existent, international norm's should be used in substitute.

II. Greenhouse Gas

2. When analyzed by life cycle assessment, GHG emissions associated with biofuel use and production must be lower than the associated fossil fuel emissions. This should include a wells-to-wheels measurement system, and both direct and indirect emissions must be included. Sources of these emissions might originate from fossil energy utilized in the growing, transport, and processing of biofuels. Greenhouse gas emissions could also stem from loss of carbon in the soil from change associated with land

conversion for biomass crop production. The ultimate goal should be to approach zero emissions well-to-wheels (full cycle).

III. Environmental Impacts

3. Biomass production must not cause the destruction or degradation of areas of high conservation value.
4. Food crops should not be displaced directly or indirectly by biofuel production.
5. Soils should not be damaged or degraded due to biomass.
6. Water resources should not be depleted or contaminated by biomass production.
7. Biomass production should not cause air pollution.
8. GMOs usage in biofuel production should be made transparent permitting buyer decision making. Precaution should be taken given the unknown long term impacts of GMOs.
9. Biomass production must not lead to crop displacement that requires further land conversion causing deforestation or destruction of critical habitat.

IV. Social Impacts

10. The well being of communities, workers, and rural populations should be increased with biomass production.
11. Food security should not be jeopardized due to biomass production.

12. Issues of child labor and welfare in developing countries must be addressed in biomass production.
13. The well-being and quality of life of the economically underprivileged should be improved with biomass production.
14. Knowledge dissemination, cohesion and harmony with in communities should increase in regions of biomass productions.
15. The production of biomass should encourage social security within the community as well as GHG reductions and waste recycling within all families.

V. Traceability

16. Production and its value chains should be traceable so that end users may discern between sustainable and unsustainable sources.

Despite these efforts, van Dam (2008) asserted that better international coordination between initiatives is required. A coordinated approach would improve coherence and efficiency in the development of sustainable biomass certification schemes and avoid excess proliferation of standards. It will also create a clearer way forward in the approach to be taken.

CHAPTER 6

CONCLUSION

In this thesis I utilized the Ostrom Institutional Analysis and Development (IAD) framework and addressed three core questions. The IAD framework is a model that enables one to conceptualize, compare, study and make connections across arenas that would otherwise be distinct from each other. By analyzing the interactions of these institutions one can see how dynamic interests combined to shape biofuel policy in the USA today. The three core questions explored in this thesis are:

- Why did first generation biofuels enjoy such extensive public and political support as late as 2007 and now are met with increasing skepticism?
- There are calls coming from stakeholders to end support for first generation biofuels by governments. What is the justification for a shift in policy?
- What is the future for biofuels in the United States, and how is it related to energy sustainability?

I have identified five action arenas in my analysis; three collective choice arenas – the Federal Government of the United States, the World Trade Organization and the United Nations Framework Convention on Climate Change and two operational arenas – the global oil and oil products markets and the global grain markets. I have shown the role these action arenas all played in how the support for bioethanol unfolded in the United States. The emphasis on corn bioethanol resulted from the complex interplay between these action arenas that created the context for policy support from the US Federal Government from the 1970s until the mid 2000s. Generally speaking, changes in the action arenas all tended to reinforce interest in grain ethanol. That is not to say there were no issues raised during the early time period. Issues often were identified, but they had no action arena that made them a priority.

It was not until 2007 – 2008 that concern about bioethanol began to come to the foreground, when trends in two action arenas began to cause divisions in what was a unified biofuel support base. The first action arena to show concern was the UNFCCC, and activities related to it where biofuels in general, but especially bioethanol in the United States, came under heavy scrutiny for its secondary impacts on the environment through land use change and impact on water use. Later, concern developed about the impact of corn based ethanol on grain markets, and the affordability of the food supply. Once powerful action arenas began to be affected, pressure rose rapidly on corn based ethanol. The United States Government responded partially by mandating the use of non-food crops for production of ethanol, but has not completely abandoned support for corn based bioethanol.

The underlying tension among action arenas remains largely unresolved, and will likely cast a shadow over the biofuels industry until new technologies emerge that can balance the interests among the five action arenas and create greater alignment among them. In the absence of greater alignment the future for biofuel is likely to look much like the past. Policy will largely support corn based bioethanol at its current level, along with modest research support for second generation technologies, but not at a transformation level, where government support for new technologies, and the infrastructure to deploy them, are made available and sustained over many years. In this case, the role of biofuels in the future will look broadly like the EIA Energy Outlook projections published in 2009 and 2010.

There are possibilities for a different kind of future. A global climate agreement, completion of the Doha round of negotiations, another spike in energy prices, or the emergence of a new disruptive technology could all create conditions for tighter alignment of interests among the IADs leading to more aggressive policy measures to promote biofuels. It remains difficult to predict how this scenario would play out in detail, but one prediction that would certainly be true is that biofuels will need to be made more sustainable.

Multiple organizations with a range of stakeholders have joined to create a scheme of criteria and indicators to ensure biofuels sustainable development. Research and development on second generation biofuels is underway, and if successful will largely eliminate the drawbacks associated with first generation fuels. The technologies with the largest present following are algae biodiesel, cellulosic ethanol and biobutanol. The success of these technologies in mitigating the concerns with first generation biofuels does not guarantee success in the market place but is a prerequisite for any significant role in the world's energy future.

In summary, I make the following conclusions:

- The IAD framework is a useful construct to look at the full suite of issues and players in the biofuels debate. Through the analysis in this thesis that characterized the nature of these action arenas and the forces that drive them, I have created a framework for understanding biofuel policy drivers that will shape the future of biofuels.
- This set of action arenas will likely be a sufficient set for analysis well into the future. While new policy drivers could emerge, they are unlikely to appear inside an action arena other than those mentioned in this thesis. It is hard to see how another substantial action arena can arise that is as important as those I have assessed. It is thus more likely, new policy drivers will be subsumed into one of these arenas. For example, greentech, land use change or energy security do not have their own action arenas. Considerations arising around these issue would likely be subsumed into the UNFCCC or US Federal Government.
- A broad conclusion from this analysis is that a compelling case for supporting corn ethanol based on its ability to reduce greenhouse gas emissions and improve national energy security cost effectively is yet to be made. The only meaningful source of support is coming from

the political demands from the agricultural sector. The scientific and economic case for corn ethanol has not been made. Even within agriculture, sector divisions are becoming more important between agribusiness and rural income supporters. It's impossible to predict how the tensions among the action arenas will be resolved. But it is instructive to note, that there is at the moment, no biofuel that is rapidly progressing towards large scale commercialization.

- There are significant issues with first generation biofuels that limit their desirability as fossil fuels substitutes. This includes, but is not limited to, energy balance, net emissions savings, land-use change, biodiversity loss, water competition, food versus fuel, and rising grain prices.
- Completing the Doha round of negotiations would significantly change the landscape for biofuels, as a core mechanism for supporting farmers during weak grain prices would be removed. The WTO negotiations were stalled over most of the first half of 2010, but by late July Director-General Pascal Lamy was reporting a "new dynamic" with hopes that progress can still be made. If the DOHA round is completed based on the current draft of the agricultural section, deep cuts in agriculture subsidies will be required in the US and Europe.
- An International agreement to substantially reduce greenhouse gas emissions could also change the landscape for biofuels, but new

legislation looks unlikely in the near future. In the US Senate the Kerry-Lieberman climate bill to commit the US to GHG reduction targets is stalled with little evidence that will change in 2010. In the absence of a US climate bill, there will be little drive coming from policy for substantial changes globally and in the US driven by climate considerations.

- Both grain and oil markets are likely to remain volatile with oil prices trending higher than early in the decade, but there is no indication that either will be sufficiently unsettled to be a defining driver of new policy.
- Even though many hoped biofuels would be contributing to greenhouse gas reductions and greater energy security by now, there is little prospect for a significant contribution in the near term without greater alignment among the action arenas. In the absence of greater alignment, business as usual usually will prevail, and the future role of biofuels will look much like EIA projections. A role that is not material.
- Greater alignment could result from a number of factors and propel biofuels toward a more important future. The details of that future are also unpredictable except that biofuels will need to be more sustainable.

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