Washington Internships for Students of Engineering

Biofuels Policy & Regulatory Issues: Applying Greenhouse Gas Emissions Lifecycle Assessment

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Preface

About the Author

Jennifer Christensen graduated from Texas A&M University in December 2008, with a bachelor's degree in chemical engineering. She will begin a PhD program at the University of Texas in the fall of 2009, in chemical engineering. Her interest in lifecycle assessment methodologies originated from being a teaching and research assistant with Dr. Lale Yurttas. The American Institute of Chemical Engineers (AIChE) has sponsored her involvement in the Washington Internships for Students of Engineering (WISE) internship program in the summer of 2009. This paper is the final deliverable for the WISE program.

The WISE Program

The WISE program began in 1980, as a way to encourage engineering students to become more interested in and capable of influencing policy decisions that affect science, technology, and engineering. In today's society, it is important for engineers to take an active role in developing scientific based policy, and the WISE program is one effort to increase this active participation. The basic goal of the nine week internship is for students to write a policy paper that captures the pertinent issues of a topic at the interface of engineering and policy. Throughout the nine weeks, students meet with various agencies and organizations to learn about their interactions with governmental processes and procedures, as well as pertinent information regarding their individual paper topics.

Acknowledgements

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Abstract

The United States government in the last five years has committed the nation to a ramped increase of biofuel production through the Renewable Fuel Standard (RFS) program. Unlike most other technologies, the policymaking regarding biofuels has been ahead of the scientific research, specifically in analyzing and understanding the overall environmental impacts of increased biofuel production.

Currently, the Energy Independence and Security Act (EISA) of 2007 defines four biofuel categories that qualify for the RFS program. The category definitions hinge on different lifecycle greenhouse gas emission (GGE) reduction criteria as compared to a 2005 petroleum baseline. As the enforcing regulatory agency, the greatest challenge that the Environmental Protection Agency (EPA) faces is properly applying lifecycle assessment methodologies to biofuel and petroleum pathways in order to produce the most certain and accurate results.

Many contentious issues, including inconsistent scope definition, modeling deficiencies, and questionable methodological assumptions regarding the application of lifecycle assessments have been raised by various stakeholders. There are no international standards for applying lifecycle methodologies to biofuel pathways, and there are only limited standards that discuss the general application of lifecycle assessments to consumer products. This paper will analyze the various policy and engineering issues associated with applying lifecycle assessment methodologies in a regulatory manner, specifically to biofuel supply pathways.

Regarding the current RFS program, I recommend that the federal government (1) reevaluate the EISA mandated baseline and (2) realign subsidy programs to promote the development of second and third generation biofuels. In the same manner, I recommend that the EPA (1) use consistent scientific methods to determine the scope, system boundaries, time horizon, and discounting technique, as well as (2) issue a statement regarding the inequity caused by the current EISA mandated baseline.

For future policy decisions at the interface of energy and the environment, I recommend that the federal government (1) utilize lifecycle assessment methodologies to make better overall energy policy decisions and (2) conduct a lifecycle assessment with a

wider scope to capture all environmental effects of a low carbon fuel standard (LCFS). I recommend that the EPA should work with (1) fellow agencies to streamline the development and application of lifecycle assessments in future regulatory programs and (2) the American National Standards Institute (ANSI), as an International Organization for Standardization (ISO) member, to standardize lifecycle assessment methodologies. The American Institute of Chemical Engineers (AIChE) can also play an active role in promoting the use of lifecycle assessment methodologies in future policy decisions through collective efforts from (1) the Governmental Relations Committee, (2) the AIChE Energy Initiative, (3) the Institute for Sustainability, and (4) the Society for Biological Engineers.

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1. Introduction

Chemical engineers have specialized in process engineering related to the refining of fossil fuels for decades. Today, chemical engineers are called to utilize these same engineering principles in the development of new chemical processes to produce renewable fuels from second and third generation biomass feedstocks, such as lignocellulose and algae, respectively. Chemical engineers are not only vested in the engineering design of new biofuel processes, but also in the development of lifecycle assessment methodologies to account for environmental impacts of increased biofuel production, such as the global warming potential of greenhouse gas emissions (GGE). Chemical engineers are specially trained in material and energy balance calculations, which is the scientific basis of the lifecycle assessment methodology. The system wide accounting of GGE from fuel pathways is a challenging issue that must be addressed by chemical engineers in conjunction with other academic disciplines.

To date, the United States government has passed various laws, the most recent being the Energy Independence and Security Act (EISA) of 2007, that have mandated the use of renewable fuels through the renewable fuel standard (RFS) program. These mandates, in addition to many different tax incentive and loan programs, have confirmed the United States' interest in the development of renewable fuels from biomass feedstocks. The corn-based ethanol industry has grown significantly in the last several years as a direct result of the mandated blending requirements. Processes utilizing lignocellulosic feedstocks, or grassy, fibrous, and woody biomass, are being pursued as the second generation of biofuel technology and are expected to be the short term relief option to corn-based ethanol. Algae are the most promising third generation feedstocks that are being developed as more long term solutions.

A recent damper has been put on the biofuels industry due to significant questions being raised as to the true environmental impact of increased biofuel production. The basis of the argument is that indirect consequences, such as indirect land use change, caused by increased biofuel production in the United States actually increase lifecycle GGE associated with biofuels as compared to their fossil fuel counterparts. The current law, the EISA, mandates that biofuels meet a minimum lifecycle GGE threshold in order to qualify as a renewable fuel under the RFS program. However, the political and scientific communities do not agree on the scope of the lifecycle assessments, nor the current assumptions and models used to quantify emissions from direct and indirect sources over time. The Environmental Protection Agency (EPA) has released its proposed rule acting on the EISA mandate and detailing their development and application of lifecycle assessment methodologies for the public review period.

The national interests for developing renewable transportation fuels include national security, economic growth, and environmental protection. However, for once, the policy has gotten ahead of the science. Accurate and comprehensive lifecycle assessment methodologies and models must be developed to properly account for GGE from both direct and indirect sources. Otherwise, there is no point to advance renewable fuels when promoting greater domestic fossil fuel production will accomplish the same goals at a lesser cost.

2. Background

2.1 Legislative History

The oil embargoes of the 1970s sparked the establishment of incentive based programs that promoted technological advancement in biofuels production and fostered their market transition and competition against fossil fuels.[1] In the last 28 years, there have been 24 active, federally funded programs related to the advancement of biofuels.[2] Three pieces of federal legislation most significantly affected the development of the biofuels market over the last 30 years: the Clean Air Act Amendments (CAAA) of 1990, the Energy Policy Act (EPAct) of 2005, and the Energy Independence and Security Act (EISA) of 2007.

2.1.1 Clean Air Act Amendments of 1990

In order to address rising concerns over decreasing air quality in major U.S. cities due to increased air pollution from an ever growing transportation sector, the CAAA created a national reformulated gasoline (RFG) program.[3] Beginning in 1995, gasoline in certain U.S. cities had to contain a minimum amount of cleaner burning hydrocarbons, or oxygenates, according to the RFG program.[4] The two most prominent oxygenates produced and blended for the RFG program were ethanol and methyl tertiary butyl ether (MTBE).[5] Brent Yacobucci discussed how the CAAA provided the preliminary market demand for biofuel production at the American Chemical Society (ACS) briefing on biofuels in August 2008.[6] He discussed that after discoveries of MTBE's carcinogenic characteristics and water pollution potential, states began banning the use of MTBE, causing an increase in ethanol demand that boosted biofuel production and infrastructure even more. Figure 1 from the Alternative Fuels and Advanced Vehicles Data Center (AFDC) shows this shift in market demand. As a note, the y-axis is consumption in millions of gallons of gasoline equivalents based on energy.

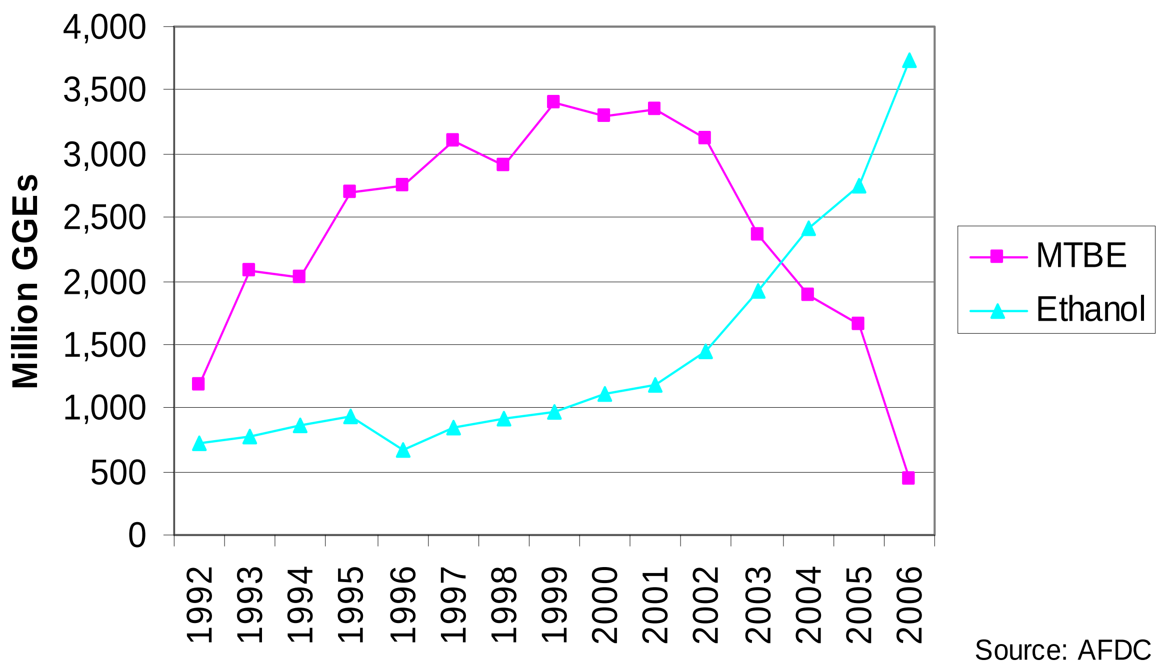

Figure 1: U.S. Oxygenate Consumption by Year[7]

The RFG oxygenate blend requirement came under heavy scrutiny after a National Research Council (NRC) report questioned its environmental validity due to an increase in ozone producing pollutants, such as nitrogen oxides and volatile organic compounds, from the use of oxygenated fuels.[8]

2.1.2 *Energy Policy Act of 2005*

Beginning in 2006, the EPAct repealed the minimum oxygenate requirement of the RFG program, but created a renewable fuel standard (RFS) program that mandated increasing blend volumes of renewable fuels into the nation's gasoline supply.[9] The EPA was given regulatory control over implementing the RFS program in consultation with the Department of Energy (DOE) and the U.S. Department of Agriculture (USDA) because it was an amendment to the CAAA.[10] According to the law, the EPA established a trading program based on renewable identification numbers (RIN) that tracked renewable fuel production and assured compliance with yearly quotas.[11] EPAct's maximum mandate required 7.5 billion gallons of renewable fuels to be used in 2012.[12]

Whereas the original purpose of the RFG program was to improve air quality by reducing pollutants, Yacobucci recognized in a Congressional Research Service (CRS) report that the implementation of the RFS had much to do with the ethanol industry's lobbying powers and interests to protect the weakened biofuels market after the RFG oxygenate requirement was repealed.[13] He acknowledged the ethanol industry's policy selling points as increased energy security and fewer environmental impacts as compared to petroleum fuels. The claim of reducing environmental impacts, specifically GGE, opened a wide political and technological debate.

2.1.3 *Energy Independence and Security Act of 2007*

The EISA increased the yearly blending volumes and expanded the lifetime of the RFS to climax at 36 billion gallons in 2022.[14] Whereas the EPAct only mandated blending volumes in the national gasoline supply, the EISA established renewable volume requirements for all transportation fuels, including "gasoline and diesel fuel intended for use in highway vehicles and engines, and nonroad, locomotive and marine engines."[15] Additionally, the EISA established a lifecycle GGE criterion that defined four categories of biofuels. A biofuel's eligibility for the RFS program is dependent on meeting the lifecycle GGE requirements for one of the established categories.

The EISA was the first piece of federal legislation to recognize the concept of lifecycle assessment methodologies and to utilize the methodology as a regulatory tool for reducing environmental impacts, specifically global warming potential from transportation fuels.[16] The EISA definition of lifecycle GGE clearly laid the ground rules for the EPA's work in developing a lifecycle assessment. As seen below, the definition explicitly requires the inclusion of indirect land use changes, as well as other indirect emission sources.

> The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.[17]

The EPA issued their proposed rule in May 2009, which outlined the methodology and modeling techniques used to quantify lifecycle GGE from various fuel pathways. The inclusion of emissions resulting from indirect land use changes is one of the most contentious components of the fuel cycle analysis. The public comment period was extended to September 2009, in order to effectively respond to public concerns and optimize the lifecycle assessment with the best current technology and methodology.

2.1.4 Low Carbon Fuel Standard Legislation

The 110th and 111th Congresses have shown increasing interest in implementing a national low carbon fuel standard (LCFS); however, their efforts to pass a bill with this legislation has so far failed to make it to the President's desk.[18] Most recently, H.R. 2454 in the 111th Congress had originally proposed replacing the RFS with a LCFS; however, the LCFS was removed from the introduced bill in an effort to push it through the House of Representatives.[19] At the state level, California leads federal legislation by having implemented a LCFS in 2009, which mandates a 10% reduction in transportation fuels' carbon intensity by 2020.[20]

As Yacobucci discusses in a CRS report, the purpose of a LCFS is to systematically reduce the carbon intensity of all transportation fuels, including, but not limited to biofuels.[21] Whereas the RFS mandates production volumes specifically for biofuels, a national LCFS would not mandate renewable fuel volumes; instead, it would rely on industry wide compliance to the standard as determined by the application of lifecycle assessment methodologies to calculate baseline and renewable fuel carbon intensities. An in-depth analysis of the LCFS policy is out of this paper's scope. However, what is pertinent to this paper is that the development and application of a LCFS policy depends on the same scientific methodologies and modeling used in the lifecycle assessment of fuel pathways in the RFS.[22]

2.2 Defining Biofuels

Feedstocks are raw material inputs to the different processes that produce a fuel. Renewable fuels are made of feedstocks that can be naturally replenished on a short time table relative to their consumption rate. Fossil fuels, such as natural gas, coal, and oil, are derived from plant and animal feedstocks that have decayed for millions of years at high temperatures and pressures, and therefore, are not considered renewable. Biomass is considered a renewable feedstock because it can be replenished on a yearly basis from existing plant derived materials. Biofuels are fuels in a liquid state created from biomass feedstocks through various chemical, biological, and thermal processes. Accordingly, biofuels are types of renewable fuels as they are made from biomass feedstocks.

Both the EPAct and EISA define the term renewable fuel, but not necessarily the term biofuel. In the EISA, renewable fuel is defined as a "fuel that is produced from renewable biomass and that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel."[23] Essentially, the term renewable fuel is synonymous with the term biofuels in the EISA, and that convention will be used in this paper as well. This convention arises from the fact that the biofuels industry is the only mature renewable fuel industry at the commercial scale.

The scientific and policy definitions begin to diverge in the definition of biomass. According to the Department of Energy (DOE), biomass is "all plant and plant-derived materials including animal manure, not just starch, sugar, oil crops already used for food and energy."[24] The EPAct actually did not define biomass, but left the implied definition nearly as broad as the scientific definition. The EISA explicitly defined renewable biomass and significantly narrowed the feedstocks that met the new criteria in order to prevent the abuse of natural resources due to increased biofuel demand.[25] Whereas the

EPAct allowed “dedicated energy crops and trees” to be feedstocks,[26] the EISA only allowed crops from previously cultivated lands and trees from previously managed farms to qualify.[27] One litigious point in the debate for H.R. 2454 with the House Agriculture Committee was expanding the current RFS definition of renewable biomass to include “a large potential pool of woody biomass, as well as biomass from federal lands.”[28]

Despite the contraction or expansion of the biomass definition, there are still potentially endless different types of biofuels due to the many different types of feedstocks and production processes. The EISA took another major step in defining biofuels when it implemented a lifecycle GGE threshold for four different biofuel categories. The stricter definitions in the EISA focus on creating a sustainable and low carbon emitting biofuels industry. The four biofuel categories identified explicitly by the EISA are conventional, cellulosic, biomass-based diesel and advanced biofuels.[29] As the EISA is the current law, this paper will analyze these four biofuel categories, while at the same time recognizing that more individual pathways for biofuel production exist.

2.3 Types of Biofuels & Brief Technological Background

2.3.1 Conventional Biofuels

According to the EISA, conventional biofuels are defined as “renewable fuel that is ethanol derived from corn starch.”[30] Additionally, the EISA established a 20% lifecycle GGE reduction criterion for conventional biofuels from biorefineries built after December 19, 2007; however, corn-based ethanol from preexisting facilities are grandfathered into the conventional biofuels category without having to meet the lifecycle GGE criterion.[31] Unlike the EPAct, the EISA caps the amount of conventional biofuel, from new or old refineries, that can qualify in the RFS program at 15 billion gallons per year from 2015 to 2022.[32]

Ethanol is an alcohol that can be produced from a wide variety of plant derived feedstocks, and therefore, the type of conversion processes and technologies utilized in ethanol production depend on the individual feedstock used, such as corn, sugarcane, or cellulose.[33] Corn is a starch-based feedstock that is easily converted into ethanol by biochemical conversion employed in two types of industrial processes: wet mill or dry mill.[34,35] In either wet mill or dry mill processes, the corn starch is reduced to simple sugars, which are fermented to produce ethanol. Due to the relatively standard technology employed in the wet mill and dry mill processes, over 90% of U.S. ethanol is produced at a commercial scale from corn feedstocks.[36] Figure 2 from the AFDC shows the rapid increase in ethanol consumption since the implementation of the RFS program.

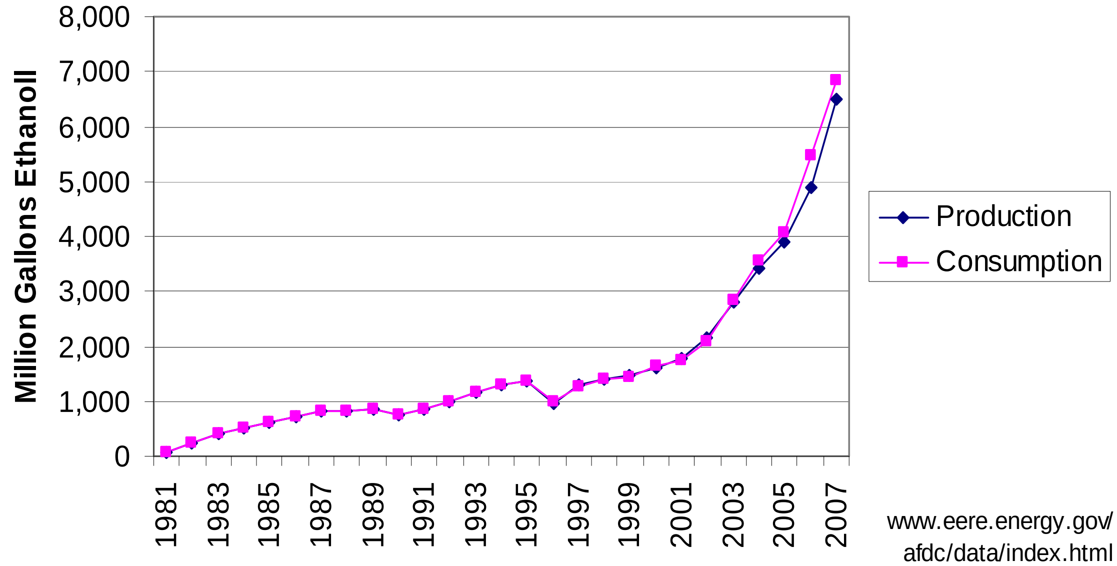

Figure 2: U.S. Production and Consumption of Fuel Ethanol[37]

2.3.2 Cellulosic Biofuels

According to the EISA, cellulosic biofuels are defined as "renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions…that are at least 60 percent less than the baseline lifecycle greenhouse gas emissions."[38] The RFS requires production volumes for cellulosic biofuels beginning in 2010, with 100 million gallons and escalating to 16 billion gallons in 2022.[39]

Cellulose, hemicellulose, and lignin are collectively known as lignocellulose and provide the structural rigidity of vegetation.[40] Examples of lignocellulosic feedstocks for biofuel production include grass, scrap wood material, and corn stalks, or in other words, vegetation that is not in the food chain and normally considered waste.[41] Unlike starch-based feedstocks, lignocellulose does not easily succumb to biochemical conversion and requires acidic and enzymatic hydrolysis to break the polymers into basic sugars for fermentation.[42] Thermochemical processes, such as gasification and pyrolysis, are required to convert non-fermentable lignocellulose into synthesis gas and biocrude, respectively.[43]

As the cellulosic biofuel production processes are more complex, they have required more research and development efforts within academia and industry, which has slowed their entrance into the commercial market. Within the last year, cellulosic technology has moved from the laboratory bench to the pilot plant and demonstration plant phase for further scalability studies. According to the Renewable Fuels Alliance, there are two cellulosic biorefineries with production capacities of 40 million gallons per year or more that are currently under construction and predict to be online by 2011.[44] However, as Steven Ashley acknowledges, the current economic downturn has slowed down, but not stopped, the advancement of cellulosic technologies.[45]

2.3.3 Biomass-Based Biodiesel

According to the EISA, biomass-based diesel is defined as "renewable fuel that is biodiesel as defined in section 312(f) of the Energy Policy Act of 1992…and that has lifecycle greenhouse gas emissions…that are at least 50 percent less than the baseline lifecycle greenhouse gas emissions."[46] The RFS quota for biomass-based biodiesel begins at 500 million gallons in 2009, and increases to 1 billion gallons in 2012.[47]

Animal fats or vegetable oils, such as found in used cooking grease or soy beans, are the typical biomass feedstocks for biodiesel production.[48] According to the National Biodiesel Board (NBB), "a fat or oil is reacted with an alcohol, like methanol, in the presence of a catalyst to produce glycerine and methyl esters or biodiesel."[49] Initially, production facilities for the sole purpose of biodiesel production did not exist, but rather biodiesel was produced from preexisting facilities that shared common feedstocks, animal fat and vegetable oil.[50] More recently, commercial scale biodiesel refineries, such as the High Plains Bioenergy biorefinery in Oklahoma, have been built next to meat processing plants for the sole purpose of converting the waste animal fat to biodiesel.[51] Figure 3 from the AFDC shows the biodiesel market growth due to the RFS program.

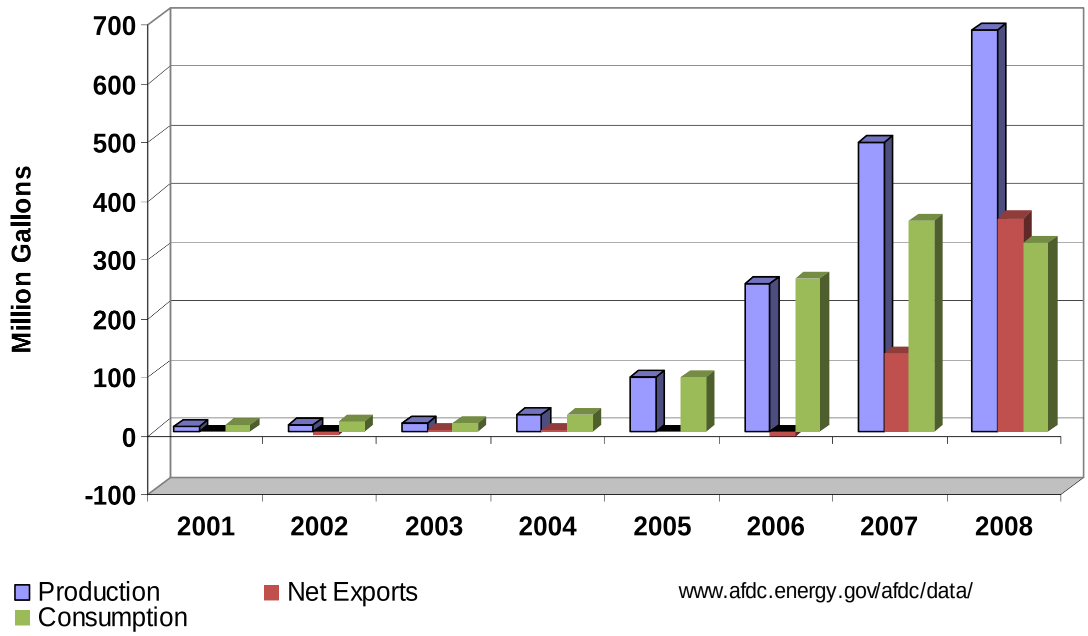

Figure 3: U.S. Biodiesel Production, Exports, and Consumption[52]

However, advanced production processes, such as the conversion of algae into biodiesel, hold the most promise for the future. Algae are able to convert carbon dioxide directly into biomass, which has a high content of lipids, or fatty molecules that can be processed into biodiesel.[53] Recently, ExxonMobil invested $600 million in algal biofuel research and development on the heels of Dow Chemical Co. beginning an algal pilot plant partnership with Algenol.[54]

2.3.4 Advanced Biofuels

According to the EISA, advanced biofuels are defined as "renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions…that are at least 50 percent less than baseline lifecycle greenhouse gas emissions."[55] Brent Yacobucci and Kelsi Bracmort discuss in the following manner how advanced biofuel production is slowly increased as compared to the maximum allowance for conventional biofuels in the RFS program.[56] In 2015, conventional biofuel production is capped at 15 billion gallons per year for the rest of the RFS lifetime. Therefore, advanced biofuels must make up the difference between the conventional biofuel production and the total renewable fuel mandate, which is a value of 5.5 billion gallons in 2015, and increases to

21 billion gallons by 2022. Biofuels that qualify as cellulosic biofuels and biomass-based biodiesel also qualify as advanced biofuels; however, the reverse is not necessarily true. Therefore, the individual volumes for cellulosic biofuel and biomass-based biodiesel count towards the overall volume for advanced biofuels. For example, in 2022, the 16 billion gallon requirement for cellulosic biofuel leaves only an additional 5 billion gallons of the total 21 billion gallon volume to be met by other biofuels that qualify as advanced biofuels, but not necessarily cellulosic biofuels.

The DOE, specifically the Biomass Program, is devoted to the development of advanced biofuels as the most reasonable fuel solution to the environmental and energy challenges currently facing the United States.[57] To support this goal, the DOE has designated almost $800 million of the American Reinvestment and Recovery Act (ARRA) funds to the promotion of advanced biofuels.[58] Specifically, $480 million is designated to support pilot and demonstration plants with an additional $176.5 million for full scale, commercial biorefineries for advanced biofuels.

2.4 Lifecycle Assessment History

Lifecycle assessment methodologies are not new; in fact, they have been utilized since the 1960s to provide greater insight to environmental issues for decision-making purposes in product and process development.[59] For over twenty five years, lifecycle assessments of direct emissions from transportation fuel pathways have been conducted by Argonne National Laboratory (ANL) through the Greenhouse gases, Regulated Emission, and Energy use in Transportation (GREET) model.[60] However, the methodology as applied to biofuels received renewed interest due to the controversy sparked in the policy and scientific communities by the Searchinger et al. article published in the February 2008, issue of Science.

According to the Searchinger et al. lifecycle assessment that included indirect land use change modeling results, biofuels did not reduce lifecycle GGE, but in fact significantly increased them.[61] Despite rebutting some of the methods, claims, and results presented by Searchinger et al., Michael Wang of the ANL and Zia Haq of the DOE purported in a follow-up letter that the article brought life to an apt debate.[62] The EISA mandated in the year prior to the publishing of the article that lifecycle GGE include indirect emissions, specifically emissions from indirect land use change.[63] Ultimately, the Searchinger et al. article highlighted the scientific and economic uncertainty of quantifying these indirect emissions and showed that the policy regarding lifecycle GGE was ahead of the scientific readiness for implementation. Inarguably, the most crucial consequence of the Searchinger et al. article was the amplification of scientific activity focusing on the development of lifecycle assessment methodologies and models, specifically relating to indirect land use changes as a result of biofuel production.

2.4 Defining Lifecycle Assessment

Unlike other environmental impact analyses, lifecycle assessment methodologies take a holistic approach to identifying and quantifying environmental impacts from the collective phases of a product or process lifecycle. According to the EPA guidelines on lifecycle development and application, there are four steps to complete a lifecycle assessment: 1) goal definition and scoping, 2) inventory analysis, 3) impact assessment, and 4) interpretation.[64]

2.5.1 Goal Definition and Scoping

The goal definition and scoping step establishes the basic guiding principles of the individual application of lifecycle assessment methodologies. Essentially, analyzers must recognize the overarching purpose of conducting a lifecycle assessment and make the following six decisions as outlined by the EPA guideline document.

1. Define the Goal(s) of the Project
2. Determine What Type of Information Is Needed to Inform the Decision-Makers
3. Determine the Required Specificity
4. Determine How the Data Should Be Organized and the Results Displayed
5. Define the Scope of the Study
6. Determine the Ground Rules for Performing the Work[65]

According to Michael Wang, determining the scope is the key to a lifecycle assessment, as it identifies the system boundary.[66] This boundary determines which phases of the lifecycle will be included in the analysis and which will not; the inclusion or absence of a phase by the boundary can cause significant differences in lifecycle assessment results.

The EPA guidelines define two types of lifecycle phases: primary and secondary.[67] The primary lifecycle phases attribute directly to the fuel cycle, and most will agree on their inclusion by the boundary, such as the production and usage phases of biofuels. Figure 4 shows the direct phases typically included in a biofuels lifecycle assessment.

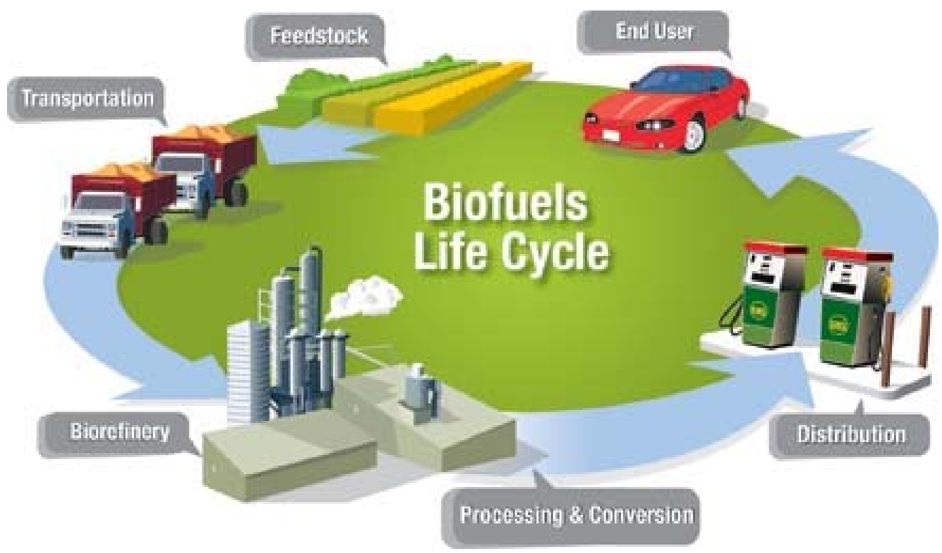

Figure 4: Lifecycle Assessment Direct Phases of a Biofuel Pathway[68]

Whereas Figure 4 can capture the chronological manner of direct phases, secondary phases cannot be summarized by a schematic. Secondary phases are also known as indirect effects as they are "effects that occur as consequences of the full fuel lifecycle."[69] In other words, indirect phases are inadvertent results of a ripple effect in the market from a policy.[70] Therefore, secondary lifecycle phases are more abstract, and not all analyzers agree on their inclusion by the system boundary.

Yacobucci discussed in an interview that while EPA analyzers still have to determine the system boundaries for the lifecycle assessment of biofuel pathways, one indirect phase is already predetermined by the EISA: indirect land use change.[71] The basic idea behind indirect land use change is that when American farmers begin to grow less crops for food and more for biomass feedstocks, land previously not in cultivation in other countries is cleared and cultivated to grow the food demanded by the global market. In other words, the increase in U.S. biofuel demand will raise the global commodity price of crops, causing an indirect effect of land use changes around the world from the current situation. This is significant for the development of the lifecycle assessment because clearing different types of vegetated land result in potentially noteworthy GGE. Therefore, the mandated placement of this phase within the system boundary has caused great debate amongst politicians and scientists.

2.5.2 Inventory Analysis

After the boundary is determined, the inventory analysis step determines which particular system inputs and outputs should be monitored. Ideally, all inputs and outputs would be tracked; however, this is impossible due to fiscal and time restraints. Therefore, the inputs and outputs that best relate to the overall goals are identified, tracked, and recorded. In the case of lifecycle GGE, the EISA defines greenhouse gases as carbon dioxide, hydrofluorocarbons, methane, nitrous oxide, perfluorocarbons, and sulfur hexafluoride.[72] Therefore, the emission data for these chemicals are collected and inventoried for the lifecycle GGE calculations in mass or volumetric quantities.

2.5.3 Impact Assessment

The impact assessment step is where the inventory data is characterized according to environmental impact categories and converted to environmental impact indicators for overall comparison.[73] The main motive for introducing lifecycle GGE reduction criteria for renewable fuels was to reduce GGE that have been recognized by the Intergovernmental Panel on Climate Change (IPCC) as contributing to global warming.[74] Therefore, the EISA actually mandates that the impact assessment of GGE be characterized and converted according to global warming potential.[75] Each type of greenhouse gas has a different global warming potential, meaning that a smaller amount of nitrous oxide can actually have the same global warming effect as a much larger amount of carbon dioxide.[76] Therefore, assessment of global warming potential instead of mandating reduction in emission quantities aims to actually meet the overall goal of mitigating global warming and climate change from the transportation sector.

In the case that the EISA focused not only on the global warming potential, but also included other environmental impact categories, such as water pollution and air quality impacts of increased biofuel production, the different categorical impact indicators would be compared and distinct value decisions made as to what degree each environmental impact could be mitigated.[77] By narrowing the scope only to global warming potential, the EISA has already made a value decision of reducing lifecycle GGE without regard to other environmental impacts.

2.5.4 Interpretation

The last step of conducting a lifecycle assessment is reviewing the analysis results and making recommendations, while highlighting the important issues and methodological assumptions taken by the analyzers.[78] In the case of lifecycle GGE calculations for the RFS program, this step is more of a technical check to ensure the proper application of methodologies and models. Additionally, this is where the lifecycle assessment results of a biofuel pathway are compared to the appropriate petroleum baseline and placed into one of the four EISA biofuel categories. Essentially, the peer review and public comment period initiated by the EPA is an extended interpretation of the proposed lifecycle assessment.

2.6 Advantages of Lifecycle Assessment

Today, people are becoming more and more concerned with the challenge of sustainably meeting tomorrow’s energy needs. The lifecycle assessment methodology has evolved to provide great insight to a product or process’ overall sustainability. Due to the design of the methodology, lifecycle assessments are capable of identifying environmental tradeoffs between categories such as air quality and water pollution.[79] Additionally, lifecycle assessments provide an overall impact review that detects the shifting of environmental impacts from one stage of the lifecycle to another.[80] The great debate concerning the lifecycle GGE of biofuel pathways is due to the inclusion of indirect land use changes that purportedly shift GGE from the usage phase to the production phase of raw materials. Rightfully conducting a lifecycle assessment allows a company, consumer, or government to compare the environmental impacts between processes and products in order to make better environmental decisions for the future.

2.7 Disadvantages of Lifecycle Assessment

While the basic principle of conducting a lifecycle assessment is straight forward and simple, the application of the methodology suffers from subjectivity, ambiguity, and value judgments that affect the applicability and acceptability of the assessment results.[81] No two lifecycle assessments will render the exact same results due to the variance of original assumptions. Differences in scope, data gathering techniques, and modeling cause contention between analyzers and render decision makers confused by varying conclusions. This accurately reflects the current status of the biofuels debate.

3. Issues

3.1 Identifying Stakeholders

The EPA identified and met with the following stakeholders in preparation for the proposed rule: "renewable fuel producers, technology companies, petroleum refiners and importers, agricultural associations, lifecycle experts, environmental groups, vehicle manufacturers, states, gasoline and petroleum marketers, pipeline owners and fuel terminal operators."[82] It is evident by the extension of the public comment and peer review period that the EPA wants, needs, and expects significant stakeholder input on the development of the final rule. And when the proposed rule results are as unnerving as in the biodiesel industry's case, stakeholders eagerly come forward to work with the EPA and to further develop the lifecycle assessment methodologies before the final rule announcement.

The EPA results for soy-based diesel only show a 22% reduction in lifecycle GGE, which significantly misses the necessary 50% reduction mark required in the RFS program.[83] According to Manning Feraci, Vice President of Federal Affairs for the National Biodiesel Board (NBB), these EPA results would eliminate 60% of the biomass feedstocks available for biodiesel production.[84] Without a change in the lifecycle assessment, the industry will be left to sink or swim, as the GGE threshold must be met in order to qualify for the biomass-based diesel category in the RFS program.[85] If biodiesel, or any other renewable fuel, cannot meet the threshold requirements, its market share will essentially evaporate.[86] In this case, the policy has served its purpose by protecting its greater stakeholders, the global population and future generations, from the global warming impacts of increased GGE from certain fuel pathways.

However, to guarantee that the policy is applied correctly and that the fuel pathways with the least amount of lifecycle GGE are promoted, the EPA's lifecycle assessment methodologies and models must be as technologically refined as possible. As the Food and Agriculture Organization of the United Nations stated in their 2008 report, "a comprehensive understanding of the relevant issues, including land-use change, and proper assessment of greenhouse gas balances are essential in order to ensure that bioenergy crops have a positive and sustainable impact on climate-protection efforts."[87]

3.2 Standardizing Lifecycle Assessment Methodologies

The nature of lifecycle assessments makes their standardization difficult. Lifecycle assessments are scientific based methodologies; however, the development of a particular lifecycle assessment is subject to the biases and social values of the individual analyzer.[88] This can be seen most readily in the first and most crucial step of a lifecycle assessment: the scope definition. No two analyzers will interpret the scope in the same manner, meaning that no two analyzers will see the system boundary ending at the same place. The divergences in system boundaries cause different lifecycle phases to be included or not included, and therefore, varying results. Standardization of lifecycle assessment methodologies is important to increase consistency of analysis results; however, defining the criteria for lifecycle assessment standards is just as subjective as defining the scope of a single assessment.

The International Organization for Standardization (ISO) has the only standards relating directly to the general development and application of lifecycle assessments. The most recent standard, ISO 14040:2006, issued in 2006, "describes the principles and framework for life cycle assessment," but is limited as "it does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the

LCA."[89] Therefore, these standards do little to reduce the nebulous nature of developing and applying an individual lifecycle assessment.

No standards exist for the application of lifecycle assessments towards transportation fuel pathways. The Roundtable on Sustainable Biofuels and the Global Bioenergy Partnership are two international initiative groups that are developing general protocols for bioenergy sustainability and biofuel lifecycle assessment methodologies, respectively. In June 2009, ISO proposed the creation of a new project committee that would focus on developing bioenergy sustainability requirements, which would potentially include lifecycle assessment standards for biofuels.[90] However, a lack of coordination in these efforts has rendered as much confusion as clarity in the application of lifecycle assessments to biofuel pathways.

The EPA has insisted that consistency was used to develop the scope, and therefore, system boundaries for all biofuel pathways and petroleum baselines in the proposed rule by applying ISO standards regarding lifecycle assessment development.[91] However, the standards' limited quality has hindered the development of the EPA's lifecycle assessments. The number of following issues related to the EPA's lifecycle assessment development and application attest to this.

3.3 Determining the Scope of Biofuel Pathways

As discussed previously, primary lifecycle phases are generally easy to classify with little to no debate about their enclosure by the system boundary; however, secondary or indirect phases are much harder to classify and are subject to significant debate. The indirect phases included in the biofuel pathways for lifecycle assessment in the EPA's proposed rule are indirect land use change, livestock emission changes, and rice methane impacts.[92] The inclusion of indirect land use change by the system boundary is the most controversial due to its potentially large effect on the overall outcome.

The most significant technical argument against including indirect land use changes in the GGE lifecycle assessment is summarized by the Renewable Fuels Association's following quote: "the current state of land use change science is far from conclusive and no consensus exists on how best to analyze the potential indirect land use impacts."[93] While this analysis of the situation is valid, it confuses the modeling issue with the primary issue of whether or not indirect land use changes should be included by the lifecycle assessment scope. Proponents of the inclusion of indirect land use changes in the lifecycle assessment recognize this and believe that “ignoring an effect that may be large simply because it is uncertain is unjustifiable.”[94]

With an infinite boundary, a lifecycle assessment would include all stages of a product’s lifecycle and render the most complete results. However, the boundary must end somewhere, as an infinite boundary would require infinite time and finances. Therefore, phases must be included depending on their scientific significance to the scope. According to the Union of Concerned Scientists, scientific and economic theories suggest that indirect land use change could be a significant phase of a biofuels lifecycle, and therefore, should be included by the system boundary.[95] Ideally, the inclusion of a lifecycle phase would be completely objective and rely solely on this type of scientific analysis and judgment. However, subjectivity enters the equation, as inclusion of indirect land use changes in the lifecycle assessment causes several social equity issues outside the bounds of scientific problem solving capability.

3.4 Equity Issues

The EISA mandate, a policy change, has affected the agricultural markets by increasing demand for biofuel feedstocks.[96] Theoretically, this increase in demand for feedstocks will lead to the increased cultivation of both domestic and international land, as well as a shifting of crops towards the more lucrative market. Zia Haq discussed in a personal interview the difference between indirect and direct land use changes, as well as the equity issues that arise with their inclusion.[97] A direct effect in a biofuel lifecycle would be an American farmer’s decision to plant corn versus wheat in order to sell his crop as a biomass feedstock to an ethanol plant. Conversely, the indirect effect of his market and policy driven decision is that the displaced wheat will still have to be produced somewhere, perhaps causing international land use change, in order to meet the world demand. Irrespective of the scientific significance of the emissions from indirect land use change, its inclusion in renewable fuel lifecycle assessments raises significant equity issues. Specifically, Haq identified and discussed three equity issues in regards to including indirect effects: 1) trade equity, 2) fuel equity, and 3) commodity equity.

3.4.1 Trade Equity

Trade equity issues arise due to the inherent nature of indirect consequences. The question that must be answered is whether or not the American famer in the above scenario should be held accountable for a Brazilian farmer's decision to cut down one more acre of rainforest for wheat production, when that American farmer has no means to counteract this resulting action.[98] Even at a higher level than an individual farmer, American policies do not have jurisdiction outside the U.S. borders, so why should international, indirect effects out of U.S. control hamstring the U.S. renewable fuels industry. The EPA responds to this issue by emphasizing the original purpose of the RFS mandate; "if the purpose is to achieve some reduction in [greenhouse gas] emissions in order to help address global warming, then ignoring [greenhouse gas] emissions because they are emitted outside our borders versus inside our borders interferes with the ability to achieve this objective."[99]

3.4.2 Fuel Equity

Fuel inequity is caused by the inconsistent application of lifecycle assessment methodologies across different types of renewable and conventional fuels, particularly the petroleum baselines.[100] The fuel equity issue arises due to the EPA's application of lifecycle assessment methodologies in conjunction with the mandated requirements.

According to the EPA's proposed rule, two future scenarios of biofuel production in 2022, one with the EISA mandate and one without, were compared in the following manner in order to account for the ripple effect that the EISA mandate caused in the biofuel markets.[101] The reference scenario was established according to the 2022, predictions from the 2007 Annual Energy Outlook produced by the Energy Information Agency. The control scenario for each individual biofuel utilized the volumes specified by the EISA in 2022, the ending year of the RFS mandate. The EPA determined the lifecycle GGE impacts for the reference and control scenarios using the economic and scientific models discussed in the following section. By taking the difference between the reference and control scenarios, the EPA ascertained the change in lifecycle GGE impacts from each individual biofuel due to the EISA mandate. Then, by dividing the change in impacts by the change in volume between the reference and control scenarios, the EPA was able to assign a lifecycle GGE impact per gallon to each individual biofuel pathway. The following excerpt from the Risk Impact Assessment issued with the proposed rule describes the results of this methodology application.

> Therefore, the results presented in this proposed rulemaking represent the per mmBtu "average marginal" impact of the change in fuel volumes considered. In other words, the [greenhouse gas] impacts were estimated for a marginal increase in fuel production, and the average impact of a marginal gallon was calculated.[102]

Once the lifecycle GGE impacts of the individual types of biofuels are known, they must be compared to the EISA mandated baseline: the average lifecycle GGE impacts from gasoline or diesel in 2005.[103] The proposed baseline boundary system includes direct emissions resulting from extraction, production, distribution, and usage, but not indirect impacts, such as indirect land use change, that occurred as a result of the policy.[104] The ethanol industry has been especially vocal in raising this equity issue and demanding that the petroleum baseline assessments account for indirect effects, "such as [greenhouse gas] emissions associated with energy-intensive Canadian tar sands development and the military involvement required to protect U.S. petroleum interests in the Middle East."[105] However, the EPA cannot use a similar scenario approach to project the effects of the EISA mandate on the petroleum industry and markets in 2022, because the law is written for a 2005 average. Therefore, the EPA proposed rule is comparing marginal biofuel impacts to an average petroleum impact baseline that has not been subjected to the same economic modeling.[106]

The EPA's rationale for conducting the lifecycle assessments of biofuel pathways in this manner was explained as follows in the proposed rule.[107] If the assessments were not conducted by comparing two future scenarios, lifecycle assessments would have to be conducted on a real time, regular basis by the EPA staff as technology improved in order to constantly update the qualification status of each biofuel pathway for an RFS category. This would require massive manpower, time, and financial investments over the lifetime of the mandate, as well as render the biofuels industry in a constant state of flux. Private industry needs a reliable and consistent regulation in order to invest accordingly. With the proposed rule using the comparison of future scenarios, biofuel pathways would be categorized for the duration of the RFS mandate and adjusted only for periodic reviews, enabling the biofuel industry to reliably create investment and business plans.

However, Brooke Coleman of the New Fuel Alliance states that the current comparison between marginal and average impacts does not accurately represent market dynamics.[108] Essentially, he concludes that the EISA has unintentionally caused an inequity in the application of lifecycle assessment methodologies between the petroleum baseline and biofuel pathways. Coleman's personal suggestion is to compare direct emissions from biofuel pathways to the direct emissions of a 2005 petroleum average, satisfying the EISA mandate, and indirect emissions from both biofuels and petroleum assessments on a marginal basis. However, the EPA must uphold the law as written in the EISA, whether or not it provides the best results.

3.4.3 Commodity Equity

Commodity inequity occurs when one commodity is held accountable for externalities that drastically alter its market, while other commodities having similar externalities are not.[109] Zia Haq used the following hypothetical example to illustrate the concept of a commodity issue.[110] An increase in coffee's popularity would cause an increase in demand for the commodity, which could result in the same type of indirect land use changes as increased biofuels production. While the biofuel industry would be held accountable for these indirect effects through mandated regulations, the coffee industry would not. Ultimately, the application of lifecycle assessment methodologies could spillover to more unsuspecting industries and markets in order to address the equity issue at hand.

3.5 Modeling Deficiencies

The equity debates, while important to further lifecycle assessment development, do not change the current status of the EPA's proposed rule. Specifically, indirect land use changes must be accounted for in the biofuel pathways, and the baseline must be the mandated 2005 petroleum average according to the EISA.[111] Therefore, the EPA, operating as a regulatory agency, must abide by the law and move to the next challenge:

economic and scientific modeling of lifecycle GGE impacts as a result of increased U.S. biofuel demand.

Ultimately, the EISA policies were ahead of the scientific community's capability to apply the law. At the time of the EISA passage, extensive direct emissions models, such as GREET, were available due to their relative scientific straightforwardness; however, models that could adequately and accurately predict the resulting emissions from indirect phases, such as indirect land use changes, did not exist.[112] Under pressure to issue a rule, the EPA integrated the existing models below and bridged their analysis gaps in the proposed rule with the understanding that modeling work would continue and the rule would be updated as appropriate.[113]

The following information of the different models employed by the EPA is summarized from the proposed rule issued in May 2009.[114] To assess the GGE from the primary lifecycle phases, the EPA utilized ANL's GREET model. The Forest and Agricultural Sector Optimization Model (FASOM) model was used to determine the domestic agricultural response to increased biofuel production, as well as the resulting emissions. The Food and Agricultural Policy Research Institute (FAPRI) model was used to estimate the international land use changes based on commodity prices and FASOM U.S. export results. While FAPRI provided the amounts of international land change, satellite imagery and data from 2001-2004 was used by Winrock International, an EPA contractor, to identify the types of land that changed in each international agricultural sector. From a compilation of IPCC Agriculture, Forestry, and Other Land Use Guidelines and Winrock data, the GGE from each type of land were estimated for the international land use change contribution. With GGE calculations from both the domestic and international land use change, the EPA could quantify lifecycle GGE increases due to the policy mandate. Figure 5 shows the main models described above, as well as supplementary models used to bridge insufficiencies.

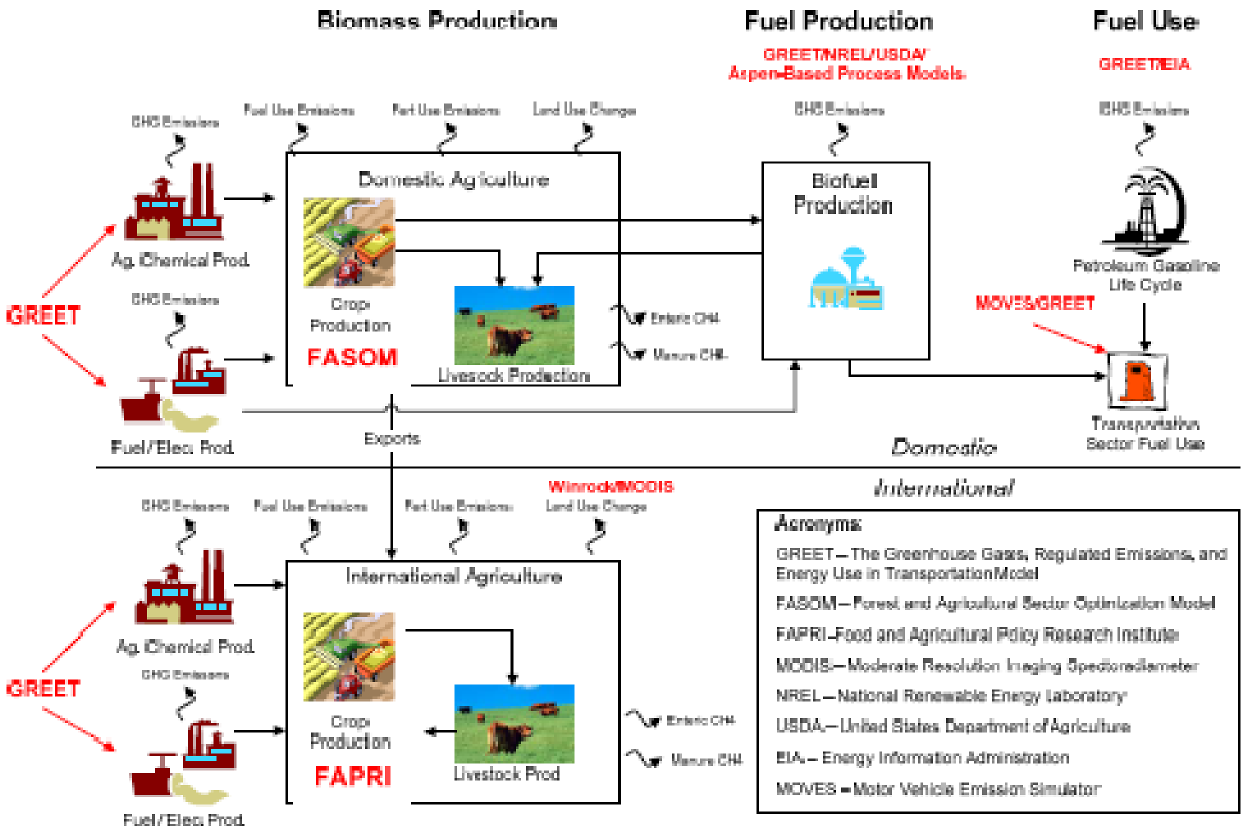

Figure 5: System Boundaries and Models and Data Sources Used[115]

Currently, the weakest link as identified by the EPA is the use of satellite data to model what types of international lands will be converted to cropland as a result of increased U.S. biofuel production.[116] According to the EPA, an alternative modeling system that could replace the FAPRI/Winrock complication in the final rule is the Global Trade Analysis Project (GTAP), a general equilibrium economic model that needs to be updated for this purpose.[117]

The individual economic models, FASOM, FAPRI, and GTAP, were never originally created for what the EPA has employed them for, nor were they created to work together in such a way as they have been forced to.[118] The integrity of a model depends on the purpose for which it was created, as the various assumptions it makes to approximate reality depend on those original parameters. Therefore, the EPA's piecemeal approach has created significant industry concerns as to the assumptions made by the individual economic models.

One noteworthy example that has raised concerns from industry stakeholders is the handling of crop yields and agricultural productivity by the existing models. At the EPA hosted workshop for the proposed rule in June 2009, Beth Calabotta from Monsanto voiced the agricultural industry's concerns regarding the FASOM and FAPRI projections of crop yields based on historical data.[119] According to her presentation, extrapolation of historical data is a flawed approach due to the important role that biotechnology breakthroughs in molecular breeding and biotech traits will play in the future. As such, she expects future crop productivity to increase at much greater rates than seen in the past, which means that less cultivated land will be needed to produce the same amount of crops in the future. Productivity assumptions are one of the keys to getting indirect land use change impacts right overtime.[120]

3.6 Determining the Time Horizon and Discount Rate

3.6.1 Determining the Time Horizon

Another specific issue regarding the inclusion of direct and indirect land use changes in the lifecycle assessment of biofuel pathways is the necessity for determining the time horizon of the analysis. As explained in the EPA's proposed rule, there are several different types of carbon emissions related to the conversion of land to cropland, including large initial emissions from lost biomass, gradual emissions from lost soil carbon, and significant forgone emission reduction capabilities from the original land type.[121] However, combating these sources of carbon debt is the fact that biofuels burn cleaner than petroleum, and therefore, over a specific time period will pay back the initial debt.[122] Figure 6 shows that the payback period for corn ethanol from a natural gas dry mill is 33 years as calculated by the EPA proposed rule.

Biofuel payback periods are potentially going to be longer or shorter than the determined time horizon in the EPA's final rule, which is a major factor in establishing whether or not a biofuel pathway will qualify for the RFS program. Therefore, there are many different opinions as to how the time horizon should be determined, as well as what it should be. Joe Fargione of the Nature Conservancy insisted at the EPA's workshop in Washington DC that this issue was strictly a policy issue that should have been addressed by the EISA.[123] However, Michael Wang of ANL discussed the downfall of this approach in a personal interview.[124] Wang warns against the possibility of using a certain time horizon in order to support preconceived policy decisions. He insists that the lifecycle assessment results should be used to influence policy decisions, but not for policy to fix analysis results by using or mandating a certain time horizon. While recognizing that the determination of a time horizon is not an exact science, he does support using sensitivity analyses to determine the best time horizon for the future.

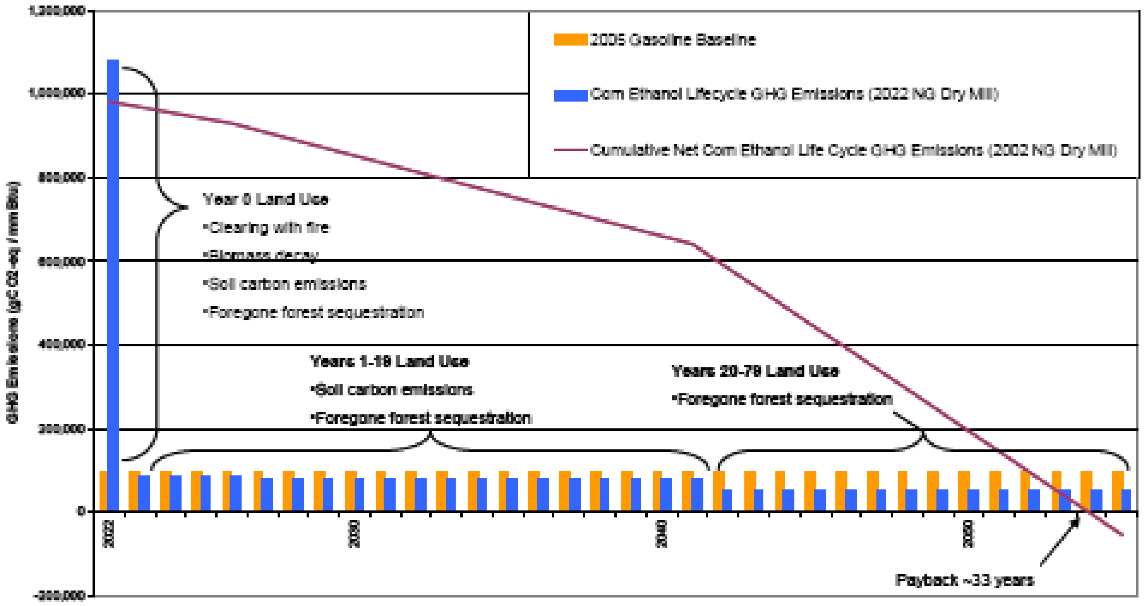

Figure 6: Corn Ethanol Payback Period[125]

3.6.2 Determining the Discount Rate

While a time horizon must be identified and applied for determining the lifecycle impacts of GGE, the EPA proposed rule recognizes a second significant factor in determining this impact: a social discount rate.[126] The basic economic idea of discounting is that the value of reducing a ton of GGE today is not the same as reducing a ton of GGE in the future. The longevity of greenhouse gases in the atmosphere causes the discounting issue to be significant. While some argue that it is inequitable to have a non-zero discount rate because this values the reduction of emissions today and tomorrow differently, and therefore, disregards future generations,[127] others argue that having too low of a discount rate will cause the current generation to bear the economic brunt for benefits they might not see in their lifetime.[128]

3.6 Interpreting the EPA's Proposed Rule Results

In the proposed rule, the EPA has used two different cases: a 30 year time period with a zero discount rate and a 100 year time period with a 2% discount rate.[129] The two different combinations of time horizon and discount rate represent the most common opposing positions and exemplify the importance of determining an appropriate time horizon and discount rate for the final rule. Figure 7 shows the results from the 30 year and zero discount rate, while Figure 8 shows the results from the 100 year and 2% discount rate.

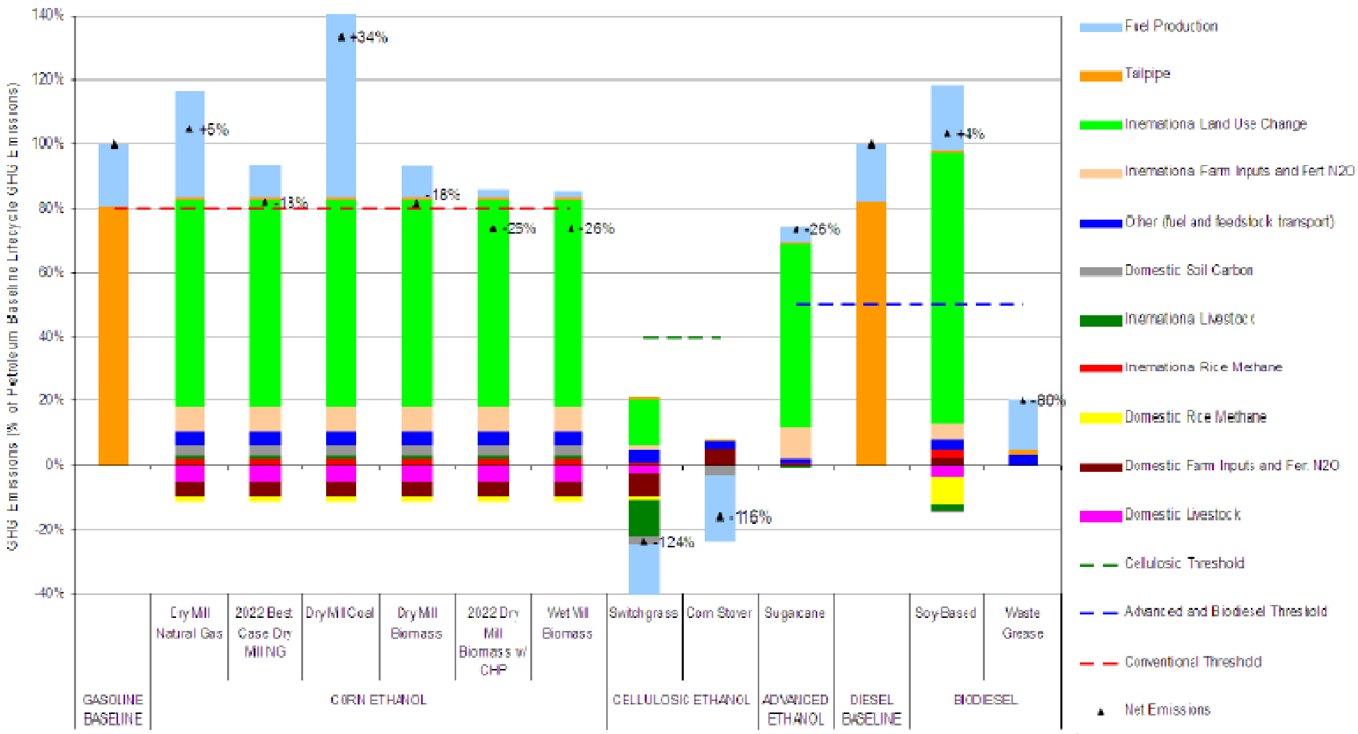

Figure 7: Proposed Rule Results with 30 Year Time Horizon and 0% Discount Rate[130]

The two varying results of the EPA's proposed rule speak to more than just the importance of determining the time horizon and discount rate. The original purpose for conducting lifecycle assessments on biofuel pathways was to categorize biofuels for the

RFS program. As can be seen in Figures 7 and 8, the only biofuels that consistently meet and exceed the lifecycle GGE requirements are cellulosic ethanol and biodiesel from waste grease. However, it must be realized that all the issues, including assumptions, methodologies, and modeling, discussed above greatly affect these results. The best technologies and methodologies to quantify and qualify lifecycle GGE within the limits of the law must be used in the EPA's final rule in order to render the most accurate results for the RFS program.

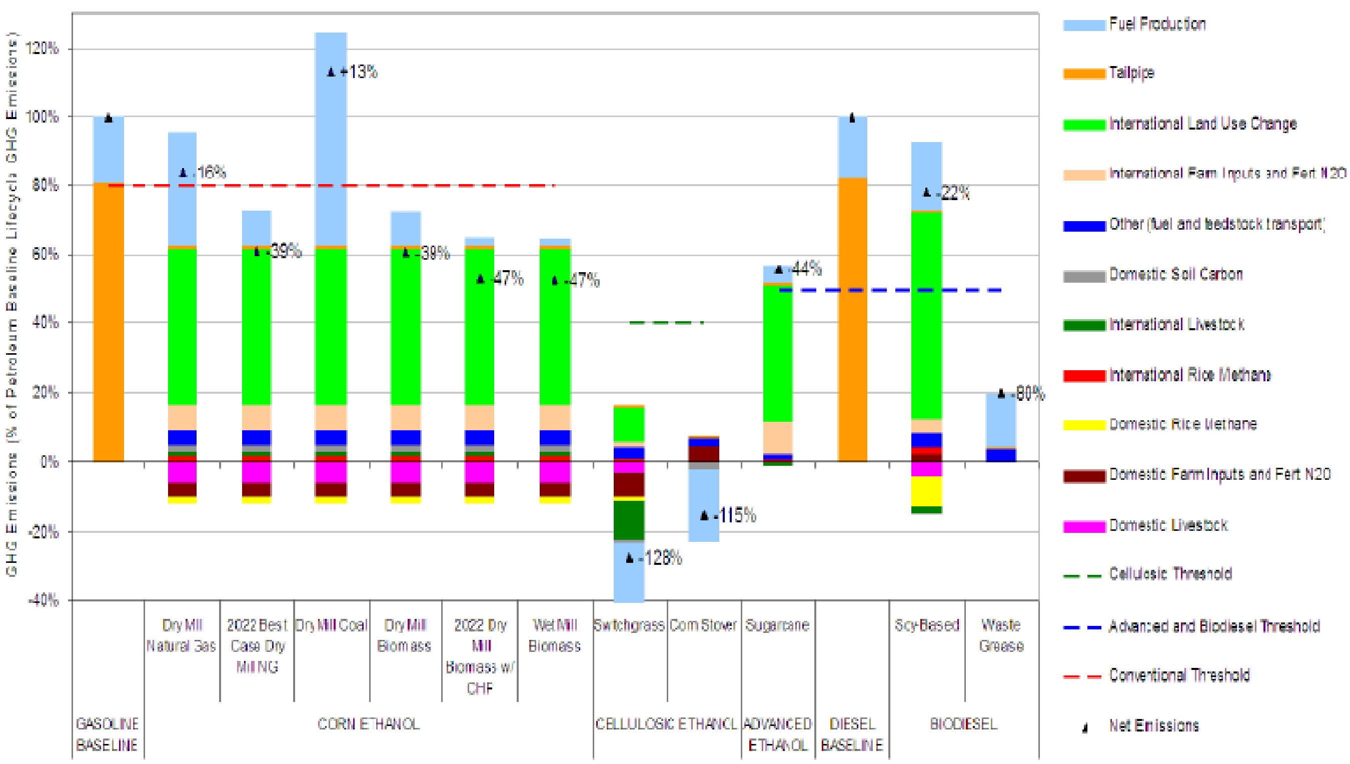

Figure 8: Proposed Rule Results with 100 Year Time Horizon and 2% Discount Rate[131]

3.8 Applying Lifecycle Assessment to Larger Scope

As discussed previously, the EPA's main purpose for applying lifecycle assessment methodologies was the qualification of biofuels in the RFS program. As the scope of the lifecycle assessment was already narrowed for the EPA by the EISA mandate, the lifecycle assessment of the biofuel pathways only focused on the global warming impacts of increased biofuel production and did not include environmental impacts in other impact assessment categories, such as water pollution or air quality. Therefore, the biofuel lifecycle assessments as required by law and as applied by the EPA do not capture the tradeoffs of environmental impacts between categories. This oversight could result in the environmental problems of tomorrow, just as the narrow-sighted ozone depletion policies of the 1990s are magnifying the global warming problem of today.[132] Had a lifecycle assessment been conducted on the use of hydrofluorocarbons, the tradeoff of environmental consequences from ozone depletion to global warming could have been identified. Widening the current RFS legislation would widen the assessment to predict other environmental impacts of increased biofuel production in addition to global warming.

Even with lifecycle assessments including more than one impact assessment category, analyzers must use social values to interpret the varying importance of different environmental impacts. As society is currently focused on the climate change consequences of global warming, the global warming impact of increased GGE would still receive the most policy efforts. However, analyzing other environmental impacts at the same time could render a better rounded policy that aims to optimize the environmental situations without augmenting to a future crisis.

4. Recommendations

4.1 Federal Government Specific

In regards to the current EISA application of lifecycle assessments to biofuel pathways, I recommend the following policy actions for the federal government.

1) Congress must change the definition of baseline lifecycle GGE to allow for the marginal comparison of biofuel and petroleum pathways due to an increase in biofuel production. This will correct the oversight in the EISA that is the cause of an inequitable situation: comparison of marginal lifecycle biofuel pathways to average lifecycle petroleum baselines.
2) Congress should streamline the many biofuel incentive and loan programs and focus most of the support towards the advancement of second and third generation

biofuels. It is clear even from the EPA proposed results that second and third generation biofuels, such as cellulosic, are capable of meeting and far exceeding the lifecycle GGE thresholds.

Overall, I suggest that the federal government utilize lifecycle assessment methodologies to their full potential by widening the scope to capture more environmental impact tradeoffs. Focusing the scope on the current environmental challenge limits the advantages of conducting a lifecycle assessment. By looking at more environmental impact categories, lifecycle assessment results can help policymakers make more responsible policies to mitigate today's environmental challenges, as well as limit the transition of challenges to the future. The following recommendations are steps to achieve this.

1) Congress should commission the National Academies of Science to formulate a report on the application of lifecycle assessment methodologies at the regulatory and policymaking levels of government. The collaborative expertise of engineers, economists, and agriculturists that the National Academy members possess will be needed to conduct this report.
2) Congress should request that the National Research Council conduct a lifecycle assessment of replacing the current RFS program with a national LCFS program. This lifecycle assessment should include other environmental impact categories in addition to global warming potential. As this issue has been brought to the floor in previous Congressional sessions, it would be proactive to request the assessment results before it resurfaces as part of a new energy bill.

4.2 EPA Specific

In regards to the current lifecycle assessment development for the RFS final rule to be issued later this year, I recommend the following for the EPA.

1) The EPA should issue a statement to Congress highlighting the equity issue of comparing marginal biofuel impacts to average petroleum baseline impacts as mandated by the EISA. The EPA must abide by the law, but issuing a statement would address stakeholder concerns, as well as be an impetus for policy reform.

2) The EPA should continue to include indirect land use change in the boundary of the lifecycle assessment not only because it is the law, but also because it is scientifically responsible. The inclusion of further indirect phases in the lifecycle boundary system must be based on scientific analysis and methodological judgments, not biased policy initiatives.
3) The EPA should work with various stakeholders, academic entities, and commercial industries to create better economic models to predict the domestic and international changes in the agricultural sector due to increased U.S. biofuel demand. Zia Haq summarized it best when he compared the current state of agricultural sector modeling to the climate change models of the 1970s; however, he finished with the bold assertion that the magnitude of progress made in 30 years of climate models needs to be done in 1 to 2 years for agriculture models.[133]
4) The EPA should assert the importance of scientifically determining a time horizon and a way to account for emissions occurring at different time frames in that horizon. These variables should not be randomly determined by potentially predisposed policy, but should be verified through scientific reasoning as Michael Wang has suggested.[134]

The EPA should work towards establishing greater lifecycle assessment protocols and standards for future applications of lifecycle assessment methodologies. The EPA should work with a wide variety of stakeholders in the standardization process in order to address the individual issues discussed above.

1) The EPA should coordinate with other vested agencies, such as the DOE and USDA, in developing greater protocols for the regulatory application of lifecycle assessments. Lifecycle assessment methodologies could be significant regulatory tools if the protocol for their application was streamlined.
2) The EPA should work with the American National Standards Institute (ANSI), the United State’s ISO representative, to standardize general lifecycle assessment methodologies. In my opinion, the EPA was thrown into a complex situation of calculating lifecycle GGE from transportation fuel pathways when the basic understanding of how to apply lifecycle assessments was not fully understood.

The lack of applicable and quality standards created a steep learning curve for the EPA, especially in regards to handling indirect or secondary lifecycle phases.

3) The EPA should also work with ANSI to influence the development of the proposed ISO project committee on the sustainability of bioenergy. Specifically, the EPA should work with ANSI to develop standards for the application of lifecycle assessments to biofuel pathways. While more robust standards for general lifecycle assessment application will help in new analyses, particular issues relating specifically to the individual application will be unique from case to case. The application of lifecycle assessment methodologies to transportation fuels has several specific issues that were discussed above, and the EPA has significant first hand experience in resolving them.

4.3 AIChE Specific

AIChE and ACS issued a joint policy statement for 2009-2012 that discusses in depth the need for a "transparent, comprehensive analysis framework for proposed energy solutions."[135] The policy paper essentially identifies the need for scientific methodologies, such as lifecycle assessments, to be employed at the highest governmental levels in order to ensure the proper development of energy policies and infrastructures for the future. AIChE as a professional organization can promote the development and application of lifecycle assessment methodologies through the following suggestions.

1) The AIChE Energy Initiative should work with the Governmental Relations Committee to conduct a white paper that discusses lifecycle assessment applications for energy policy decision making. In the public policy statement mentioned above, AIChE hints at the basic need and structure of an analysis framework; however, the society should produce a white paper that identifies the various issues and potential solutions for applying lifecycle assessments at larger governmental scales. The application of lifecycle assessments to regulating biofuel policy can be a case study.
2) The AIChE Institute for Sustainability (IFS) should also take a more active role in promoting the scientific development of lifecycle assessment methodologies.

Specifically, the IFS should host a First International Congress on Sustainability Science and Engineering that focuses on lifecycle assessment methodology development and application with cosponsors, such as the EPA, DOE, and ANSI.

3) The AIChE Sustainable Engineering Forum in conjunction with the AIChE Society for Biological Engineering should hold a series of meetings focusing on particular issues regarding the application of lifecycle assessment methodologies to biofuel pathways. Each meeting can be devoted to developing more scientific solutions to an individual issue, such as scoping, modeling assumptions, time horizon, and discount methods.

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6. Appendix I: Acronyms

ACS	-	American Chemical Society
AFDC	-	Alternative Fuels & Advanced Vehicle Data Center
AIChE	-	American Institute of Chemical Engineers
ANCI	-	American National Standards Institute
ANL	-	Argonne National Laboratory
ARRA	-	American Reinvestment & Recovery Act
CAAA	-	Clean Air Act Amendments of 1990
CRS	-	Congressional Research Service
DOE	-	U.S. Department of Energy
EISA	-	Energy Independence & Security Act of 2007
EPA	-	Environmental Protection Agency
EPAct	-	Energy Policy Act of 2005
FAPRI	-	Food and Agricultural Policy Research Institute
FASOM	-	Forest and Agricultural Sector Optimization Model
GGE	-	Greenhouse Gas Emissions
GREET	-	Greenhouse gases, Regulated Emission, and Energy use in Transportation
GTAP	-	Global Trade Analysis Project
IFS	-	AIChE Institute for Sustainability
ISO	-	International Organization for Standardization
LCFS	-	Low Carbon Fuel Standard
NBB	-	National Biodiesel Board
RIN	-	Renewable Identification Number
RFG	-	Reformulated Gasoline
RFS	-	Renewable Fuel Standard
USDA	-	U.S. Department of Agriculture
WISE	-	Washington Internships for Students of Engineering