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Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)

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Summary

The Energy Independence and Security Act of 2007 (EISA; P.L. 110-140) significantly expanded the renewable fuel standard (RFS) established in the Energy Policy Act of 2005 (EPAct 2005; P.L. 109-58). The RFS requires the use of 9.0 billion gallons of renewable fuel in 2008, increasing to 36 billion gallons in 2022. Further, EISA requires an increasing amount of the mandate be met with "advanced biofuels"—biofuels produced from feedstocks other than corn starch and with 50% lower lifecycle greenhouse gas emissions than petroleum fuels. Within the advanced biofuel mandate, there are specific carve-outs for cellulosic biofuels and biomass-based diesel substitutes (e.g., biodiesel).

To classify biofuels under the RFS, the Environmental Protection Agency (EPA) must calculate the lifecycle emissions of each fuel relative to gasoline or diesel fuel. Lifecycle emissions include emissions from all stages of fuel production and use ("well-to-wheels"), as well as both direct and indirect changes in land use from farming crops to produce biofuels. Debate is ongoing on how each factor in the biofuels lifecycle should be addressed, and the issues surrounding direct and indirect land use are particularly controversial. How EPA resolves those issues will affect the role each fuel plays in the RFS.

EPA issued a Notice of Proposed Rulemaking on May 26, 2009, for the RFS with suggested methodology for the lifecycle emissions analysis. EPA issued a final rule on February 3, 2010. The final rule includes EPA's methodology for determining lifecycle emissions, as well as the agency's estimates for the emissions from various fuels. In its proposed rule, EPA found that many fuel pathways did not meet the threshold requirements in EISA. However, its methodology was criticized by biofuels supporters. In the final rule, EPA modified its methodology to reflect some of those comments. However, some biofuels opponents counter that the final rules went too far in the opposite direction. In most cases, estimated emissions decreased (i.e., emissions *reductions* increased), leading to more favorable treatment of biofuels in the final rule.

Because of the ongoing debate on the lifecycle emissions from biofuels, including finalized regulations by the state of California for a state low carbon fuel standard (LCFS) in January 2009, there is growing congressional interest in the topic. Congressional action could take the form of oversight of EPA's rulemaking process, or could result in legislation to amend the EISA RFS provisions. Further, related legislative and regulatory efforts on climate change policy and/or a low-carbon fuel standard would likely lead to interactions between those policies and the lifecycle determinations under the RFS.

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Introduction

On August 8, 2005, President Bush signed the Energy Policy Act of 2005 (EPAct 2005; P.L. 109-58). Among other provisions, EPAct 2005 established a renewable fuel standard (RFS) requiring gasoline to contain a minimum amount of fuel produced from renewable biomass. Through 2007 the requirement was largely met using corn-based ethanol, although other fuels such as biodiesel played a limited role. The law directed EPA to establish a credit trading system to provide flexibility to fuel producers; ethanol produced from cellulosic feedstocks was granted extra credit. Also, P.L. 109-58 required that a relatively small amount (250 million gallons, or roughly 0.2% of gasoline consumption) of cellulosic ethanol be blended in gasoline annually starting in 2013.[1]

The Energy Independence and Security Act of 2007 (EISA; P.L. 110-140), signed by President Bush on December 19, 2007, significantly expanded the RFS to include diesel fuel,[2] requiring the use of 9.0 billion gallons of renewable fuel in 2008, increasing to 36 billion gallons in 2022. These mandates represent roughly 5% and 18% of motor fuel consumption by volume, respectively. EISA also requires an increasing amount of the mandate be met with "advanced biofuels"—biofuels produced from feedstocks other than corn starch and with 50% lower lifecycle greenhouse gas emissions[3] than petroleum fuels. Within the advanced biofuel mandate, there are specific carve-outs for cellulosic biofuels and biomass-based diesel substitutes (e.g., biodiesel).

Under EPAct 2005, the Environmental Protection Agency (EPA) released a final rulemaking for 2007 and beyond. Included in the rule were provisions for credit trading, as well as for generating credits from the sale of biodiesel and other fuels.[4] Because of the changes in the RFS from P.L. 110-140, EPA proposed rules in May 2009,[5] and finalized those rules on February 3, 2010.[6] Perhaps most importantly, EPA developed rules for determining the lifecycle greenhouse gas emissions from renewable fuels. As required by EISA, fuels from new biorefineries (i.e., excluding existing corn ethanol plants) must achieve at least a 20% lifecycle greenhouse gas reduction relative to petroleum fuels, and advanced biofuels (i.e., fuels other than corn ethanol) must achieve at least a 50% reduction, with cellulosic biofuels needing a 60% reduction.

To classify biofuels under the RFS, EPA must calculate the lifecycle emissions of each fuel relative to gasoline or diesel fuel. As there are specific carve-outs for certain fuels, how the lifecycle emissions of each fuel are assessed will have direct effects on the application of that fuel under the RFS. Debate is ongoing on how each factor in the biofuels lifecycle should be

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[1] Currently, world production of cellulosic ethanol is limited. No commercial-scale plants have been completed in the United States, although some demonstration-scale plants have begun producing fuel.

[2] Other fuels, such as heating oil and jet fuel, may generate credits that can offset requirements for gasoline and diesel fuel. However, there is no requirement for these fuels to contain renewable fuel.

[3] Lifecycle emissions include emissions from all stages of fuel production and use ("well-to-wheels"), as well as both direct and indirect changes in land use from farming crops to produce biofuels.

[4] Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program, Final Rule," 72 *Federal Register* 23899-23948, May 1, 2007.

[5] Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program," 74 *Federal Register* 24904-25143, May 26, 2009.

[6] Environmental Protection Agency, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule*, EPA-HQ-OAR-2005-0161, Washington, DC, February 3, 2010, http://epa.gov/otaq/renewablefuels/rfs2-preamble.pdf.

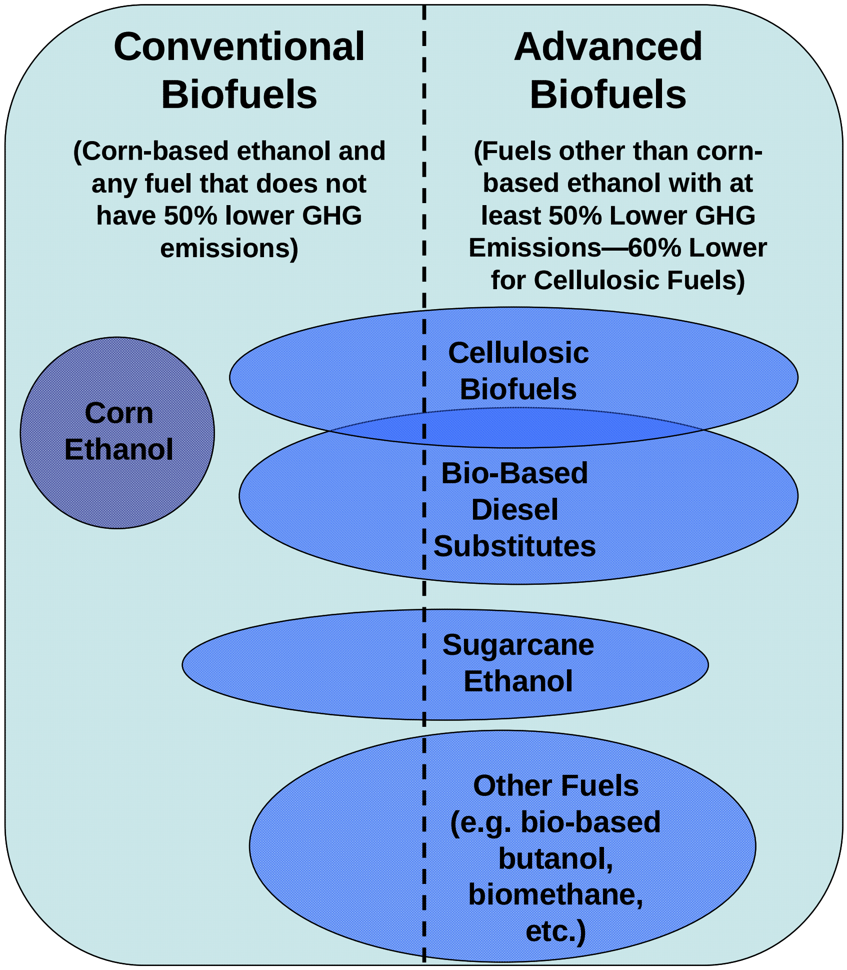
addressed, and the issues surrounding direct and indirect land use are particularly controversial. For example, whether sugar-based ethanol from Brazil is classified as an advanced biofuel or a conventional biofuel will determine whether it must compete with less expensive corn-based ethanol from the Midwest or with more expensive advanced biofuels (see **Figure 1**). If it were determined that, for example, Brazilian sugar ethanol did not achieve the 50% reduction necessary for advanced biofuels, then it could only qualify as part of the overall RFS, as opposed to the advanced biofuel carve-out. Likewise, if corn ethanol were found to not achieve the necessary 20% reduction in lifecycle emissions, then ethanol from new corn-based biorefineries would not qualify for inclusion in the RFS, while fuel from plants that began construction before December 19, 2007, is grandfathered under the law.[7]

In EPA's Notice of Proposed Rulemaking (NPRM), several fuels did not achieve EISA's threshold requirements, including sugarcane ethanol and soy-based biodiesel. However, EPA's proposed methodology was criticized by many stakeholders. In response to comments by peer reviewers and the public, EPA modified its methodology to reflect some of those criticisms. EPA made three key conclusions that lowered the land use impact of most biofuels: (1) crop yields would likely increase, requiring less additional land to grow those crops; (2) some biofuel co-products (e.g., animal feed) were more efficient than assumed in the proposal; and (3) satellite data allowed more precise assessment of what types of land would be converted.[8] In the final rule, all assessed biofuels met the threshold requirements for their category. For example, soy-based biodiesel met the 50% reduction requirement for biomass-based diesel fuel, sugarcane ethanol met the 50% reduction requirement for advanced biofuels, and corn ethanol from new natural gas-fired refineries met the 20% reduction requirement for all renewable fuels.

[7] Fuels that do not meet the stipulations of the RFS are not banned from sale or use in the United States, but they will not qualify for credits under the RFS. However, as the RFS mandates are significantly higher than expected U.S. biofuels demand in the absence of the mandates, it is likely that exclusion from the RFS will effectively be a barrier to entry into the marketplace. Qualification under the RFS has no bearing on whether fuels qualify for federal tax incentives. For example, if in 2010, ethanol consumption reached 13 billion gallons, only 12.3 billion gallons could be counted toward the RFS; the full 13 billion gallons, however, would be eligible for the ethanol blender's tax credit.

[8] Environmental Protection Agency, *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels: Regulatory Announcement*, EPA-420-F-10-006, Washington, DC, February 2010, pp. 3-4, http://epa.gov/otaq/renewablefuels/420f10006.pdf.

Figure 1. Classification of Various Biofuels Under the RFS



Source: CRS Analysis of P.L. 110-140.

RFS Requirements

Volume Requirements

Under EISA, the RFS requires the use of just over 11 billion gallons of renewable fuel in 2009, increasing to 36 billion gallons by 2022 (see **Table 1**). Within that mandate, there is a specific carve-out for advanced biofuels, increasing from 0.6 billion gallons in 2009 to 21 billion gallons by 2022. The remaining share of the RFS, which is capped at 15 billion gallons by 2015, will likely be met using corn-based ethanol, although there is no specific carve-out for that fuel (see **Figure 2**).

Table 1. Expanded Renewable Fuel Standard Requirements Under P.L. 110-140

		Advanced Biofuels			
Year	**Total RFS Mandate (billion gallons)**	**Total Advanced Biofuel Mandate (billion gallons)[a]**	**Cellulosic Biofuel Mandate (billion gallons)[b]**	**Biomass-Based Diesel Fuel (billion gallons)[b]**	**Unspecified (Effective Cap on Corn Ethanol)[c]**
2006					
2007					
2008	**9.0**				9.0
2009	**11.1**	0.6		0.5	10.5
2010	**12.95**	0.95	0.0065[d]	0.65	12.0
2011	**13.95**	1.35	0.25	0.8	12.6
2012	**15.2**	2.0	0.5	1.0	13.2
2013	**16.55**	2.75	1.0	1.0	13.8
2014	**18.15**	3.75	1.75	1.0	14.4
2015	**20.5**	5.5	3.0	1.0	15.0
2016	**22.25**	7.25	4.25	1.0	15.0
2017	**24.0**	9.0	5.5	1.0	15.0
2018	**26.0**	11.0	7.0	1.0	15.0
2019	**28.0**	13.0	8.5	1.0	15.0
2020	**30.0**	15.0	10.5	1.0	15.0
2021	**33.0**	18.0	13.5	1.0	15.0
2022	**36.0**	21.0	16.0	1.0	15.0

Source: CRS analysis of P.L. 110-140.

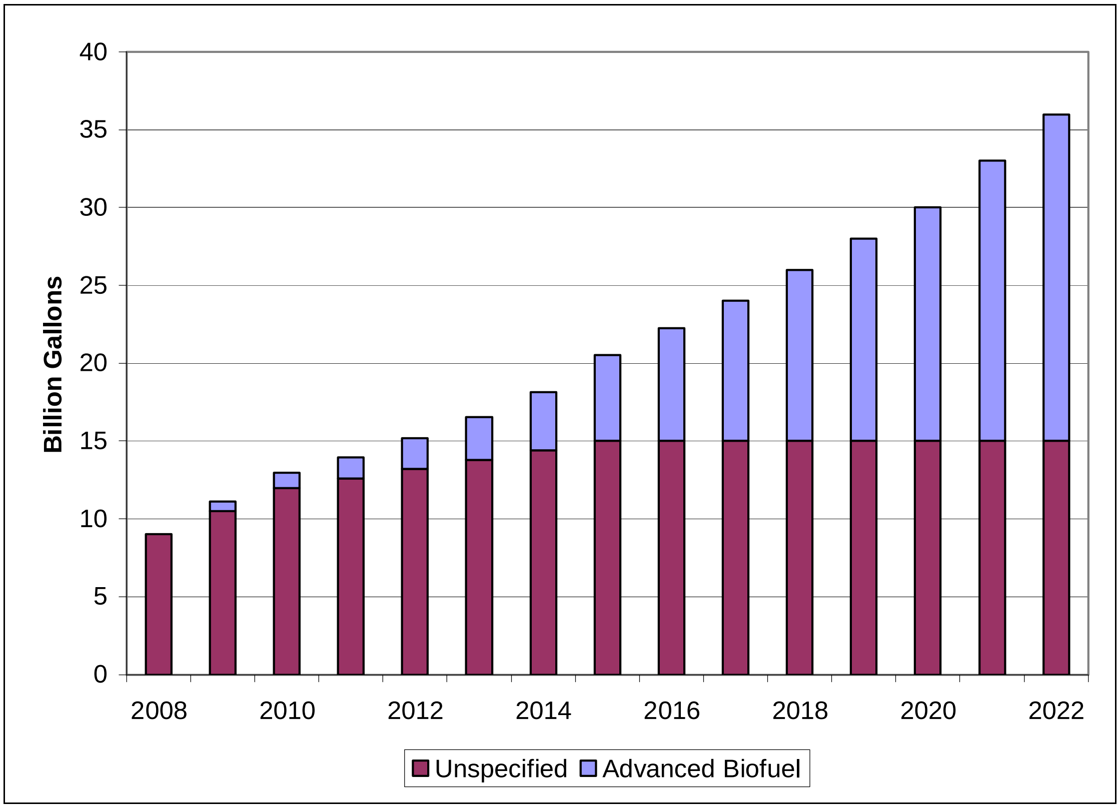
a. The advanced biofuel (i.e., non-corn-starch ethanol) mandate is a subset of the RFS. The difference between the RFS mandate and the advanced biofuel mandate—15 billion gallons in 2015 onward) is effectively a cap on corn ethanol under the program.

b. The cellulosic biofuel and biomass-based diesel fuel mandates are subsets of the advanced biofuel mandate.

c. Although this portion is sometimes referred to as a carve-out for corn-based ethanol, in fact any qualified renewable fuel may be used to meet this portion of the mandate. Therefore, this portion of the RFS effectively establishes a cap on corn ethanol under the RFS, while the actual amount of corn ethanol could be lower.

d. EISA set the cellulosic biofuel mandate at 100 million gallons in 2010, but EPA is only requiring 6.5 million gallons, more than 90% less than scheduled by EISA. EPA has the authority to waive a portion of the cellulosic biofuel mandate if the agency determines that there is not sufficient production capacity in a given year. EPA cited a lack of current and expected production capacity, driven largely by a lack of investment in commercial-scale refineries. For more information, see CRS Report RS22870, *Waiver Authority Under the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci.

Figure 2. Renewable Fuel Standard Under EISA, by Year

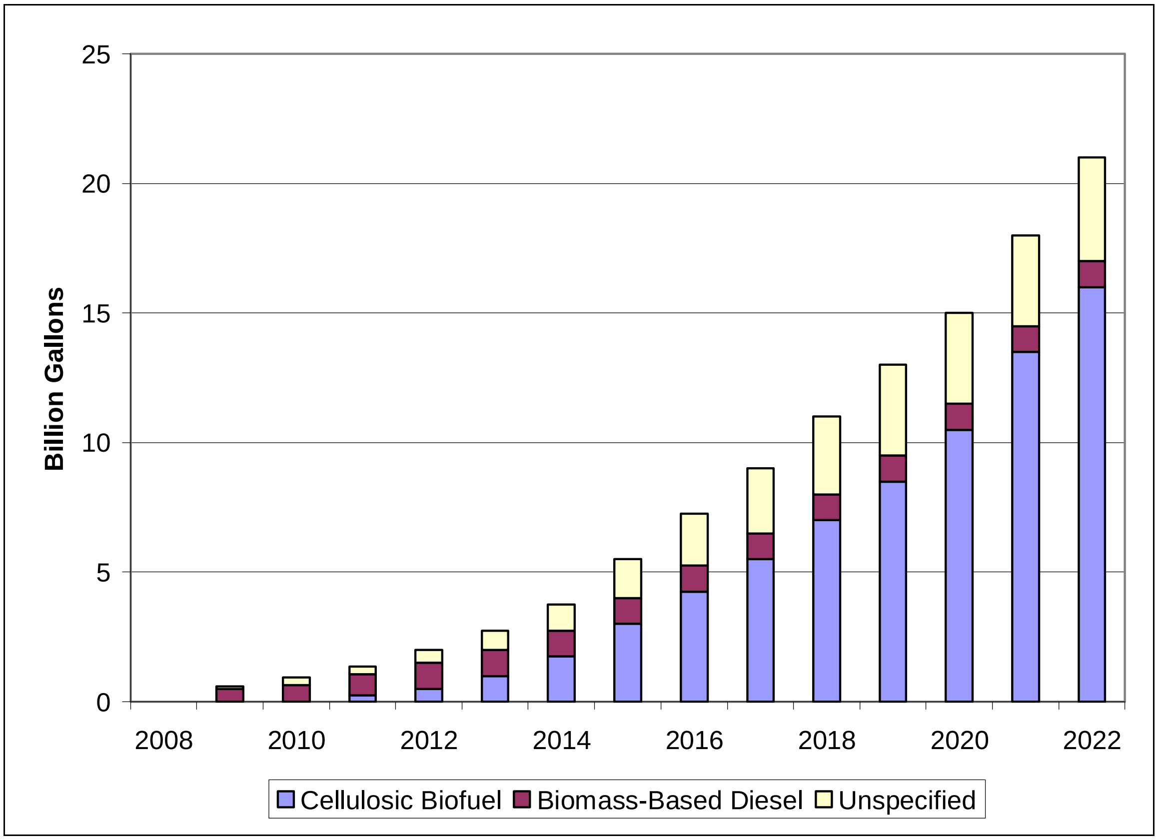


Source: CRS Analysis of P.L. 110-140.

Within the advanced biofuel carve-out, there are specific carve-outs for biofuels produced from cellulosic materials (e.g., perennial grasses, fast-growing trees)[9] and for biomass-based diesel substitutes. The remaining share of the advanced biofuel mandate is unspecified and could potentially be met using sugar-based ethanol or other biofuels (see **Figure 3**).

[9] For more information on cellulosic biofuels, see CRS Report RL34738, *Cellulosic Biofuels: Analysis of Policy Issues for Congress*, by Kelsi Bracmort et al.

Figure 3. Advanced Biofuels Carve-Outs Under EISA, by Year



Source: CRS Analysis of P.L. 110-140.

Lifecycle Requirements

To be classified as advanced biofuel, biomass-based diesel fuel, or cellulosic biofuel under the RFS, fuels must have lower lifecycle emissions relative to petroleum products (see **Table 2**). Further, conventional biofuels produced from new biorefineries must have 20% lower lifecycle emissions than petroleum products.

Table 2. Lifecycle Emissions Reduction Thresholds for Specified Biofuels Under the RFS

Reductions Relative to Petroleum Fuels

	Advanced Biofuels		
Conventional Biofuels from New Biorefineries[a]	**Unspecified Advanced Biofuels**	**Biomass-Based Diesel Substitutes**	**Cellulosic Biofuels**
20%	50%	50%	60%

Source: CRS Analysis of P.L. 110-140.

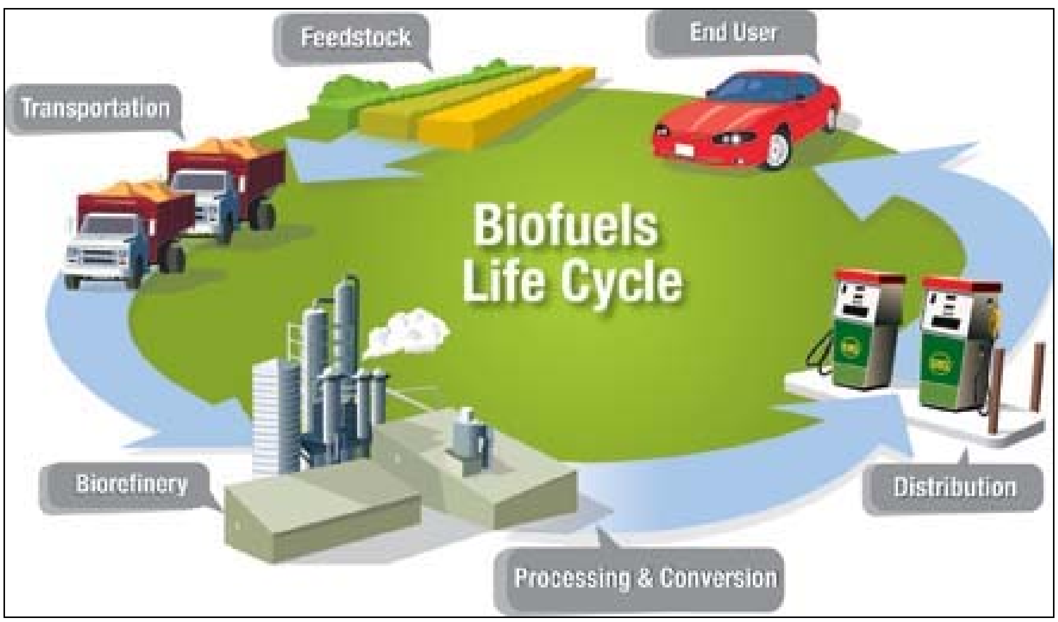
a. Facilities that began construction after December 19, 2007. Conventional biofuels from facilities that began construction before that date are subject to no lifecycle emissions requirements.

Under the definition of lifecycle greenhouse gas emissions under Section 201 of EISA, EPA must consider all significant emissions, both direct and indirect, from a wide array of fuels and feedstocks. [10] Therefore, the potential number of variables EPA must consider is high, as will be discussed below. Further, EISA does not specify the methodology for EPA to make its determinations on lifecycle emissions. Thus, EPA needed to develop the methodology for that analysis. EPA's methodology in the final rule is described in a subsequent section of this report.

Lifecycle Analysis

Estimations of the greenhouse gas emissions attributable to a fuel require detailed analysis of three key components: (1) the processes required to produce feedstocks, convert them into fuel, and deliver the fuel to the end-user; (2) the emissions from the vehicle itself; and (3) any direct or indirect changes in emissions not attributable to fuel production or use, including changes in land use. The first two components are often referred to as "well-to-tank" and "tank-to-wheels" emissions; both taken together are referred to as "well-to-wheels" emissions. **Figure 4** shows some of the main elements of the biofuels life cycle.

Figure 4. Major Elements of the Biofuels Life Cycle



Source: National Renewable Energy Laboratory.

[10] Section 201 of EISA defines lifecycle emissions as follows: "(H) LIFECYCLE GREENHOUSE GAS EMISSIONS.—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." 42 U.S.C. §7545(o)(1).

Well-to-Tank

There are many steps in producing and delivering fuel to an end-user. For gasoline, these steps include—but are not necessarily limited to—extraction of crude oil, crude oil transport, refining, gasoline transport, and delivery. For corn ethanol, these steps include corn production, harvesting, and transport; corn processing and ethanol distillation; and transport and delivery. Each of these larger steps can be broken down into smaller pieces, each of which requires energy and produces greenhouse gas emissions. For example, in the case of corn production, energy is required to operate machinery and to produce fertilizers.[11] Further, greenhouse gases are released from the application of nitrogen-based fertilizers, and from other agricultural operations. Varying assumptions of which inputs are relevant can lead to a wide range in total energy requirements, and thus, greenhouse gas emissions. Further, different assumptions about factors such as resource use, process efficiency, production yields, and the role of co-products (e.g., animal feed) can also lead to differences in emissions estimates.

Tank-to-Wheels

The emissions from the end use of the fuel ("tank-to-wheels") are easier to quantify. Assuming the carbon content of the fuel is known, then taking a given rate of consumption (the vehicle's fuel economy), estimates of carbon dioxide emissions can be calculated. Added to these are the expected emissions of any non-CO2 greenhouse gases (e.g., methane, nitrous oxide).

[11] Some analyses include the energy required to produce the machinery, and to feed farm workers.

Lifecycle Emissions Factors for Various Fuels

For petroleum fuels, potential lifecycle emissions include the following sources:

- process emissions from exploration and extraction of crude oil
- electricity generation for use in exploration and extraction of crude oil
- transportation of crude oil to refineries
- refinery process emissions
- electricity generation and use at refineries
- upstream natural gas and coal emissions (e.g., extraction and mining)
- distribution of finished product
- end-use combustion of the fuel

For ethanol, potential lifecycle emissions include the following sources:

- land use change; process emissions from lime and fertilizer production
- electricity generation for lime and fertilizer production
- process emissions from pesticide production
- fossil fuel use on farms; electricity generation for farm use
- soil emissions of nitrogen oxides
- transportation of feedstocks to biorefineries
- biorefinery process emissions; combustion of fuels at biorefineries
- electricity generation for use at biorefineries
- upstream natural gas and coal emissions
- transportation of refined fuel
- end-use combustion of the fuel

Sources: Jason Hill, Stephen Polasky, and Erik Nelson, et al., "Climate Change and Health Costs of Air Emissions From Biofuels and Gasoline," *Proceedings of the National Academy of Sciences*, vol. 106, no. 6 (February 10, 2009), p. 2082. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program, *Ethanol: The Complete Lifecycle Energy Picture*, March 2007, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/ethanol_brochure_color.pdf.

Land Use Change

Arguably, the most difficult variable to quantify in assessing fuel lifecycle emissions is the role of land use change. Land is a requisite input to grow feedstock for biofuel production. Some contend that significant land use change, both direct and indirect, will occur to accommodate annual RFS requirements. Inclusion and measurement of greenhouse gas emissions associated with direct and indirect land use change happening as a result of a burgeoning biofuels market is a pressing concern.

Particular attention is being paid to the carbon debt[12] brought about from land use change to accommodate biofuel feedstock production. Including the carbon debt may lessen the emission reduction ability of said biofuels. Measurement techniques to quantify, verify and monitor the carbon debt rely on the robustness of land use data sets and land use change models.

Controversy over Biofuels Lifecycle Analysis

The biofuels lifecycle analysis has placed scientists, environmentalists, industry representatives, and policy makers in a quandary. The lack of a precedent by which interested groups can seek guidance further complicates matters. Apprehension exists mainly regarding the land use components within the analysis and sound measurement techniques to accurately quantify the land use components. Currently, EISA (P.L. 110-140) requires EPA to account for "significant" greenhouse gas emissions from both direct and indirect land use change. As such, major implications may arise concerning the type and quantity of biofuels produced to meet RFS requirements.

Some researchers argue that greenhouse gas emissions from land use change have not been accounted for in earlier biofuel emissions estimates.[13] If so, crop-based biofuel production may result in larger quantities of greenhouse gas emissions than previously thought. Others contend that some newer models of lifecycle emissions may overstate the effects of land use. Biofuels developed from agricultural and crop waste may not be subject to the additional greenhouse gas emissions from land use change, direct or indirect.

Indirect land use change (ILUC) involves the greenhouse gas emission estimation of land cleared or converted for crop production by entities other than the feedstock producer, including the conversion of land in foreign countries. Some argue any ruling issued by the EPA that consists of ILUC is premature as the predicted impacts may be based on models using incomplete data sets, and assumptions and calculations that may not be based on sound scientific methodology or observations.

Some biofuels supporters contend that EPA should be mindful of the barriers to biofuel generation and use as the agency implements the statutory language to account for indirect land use change in the biofuel lifecycle analysis. There may be a substantial decrease in the continued development of second-generation advanced biofuels. Innovators may be drawn away from further exploration and refinement of second-generation advanced biofuels if monetary supplements or fuel credits are not granted due to a poor biofuel lifecycle analysis score.

Land use change is a relatively new subject area for researchers to simulate real-world conditions using models, economic or spatial. The certainty of simulation models for land use change compared to real world action is subject to various human and economic considerations. Quantification of greenhouse gas emissions associated with land cover and land use change are contingent upon reliable land use and land cover measurements. Techniques to quantify, verify

[12] Joseph Fargione, Jason Hill, and David Tilman, et al., "Land clearing and the biofuel carbon debt," *Science*, vol. 319 (February 29, 2008). Fargione et al. define carbon debt as the amount of CO_2 released during the first 50 years after the natural environment is converted to cropland.

[13] Timothy Searchinger, Ralph Heimlich, and R.A. Houghton, et al., "Use of U.S. cropland for biofuels increases greenhouse gases through emissions from land-use change," *Science*, vol. 319 (February 29, 2008).

and monitor emissions from land use change rely on the robustness of land use change prediction methods. Forecasting land use change—specifically conversions as a consequence of the RFS program—may prove challenging. Computer models and satellite imagery can assist decision makers with identifying land areas ideally suited for conversion assuming current land use data sets are acquired on a recurring basis.

However, the development of land use change estimates is complicated, and the methodology for determining the greenhouse gas impacts of indirect land use change is in the very early stages of development. According to the Roundtable on Sustainable Biofuels (RSB),

> It is difficult to link direct causality of land use changes in one region or country to biofuel production in another. Nevertheless, the potential for negative indirect impacts is high, and within the spirit of the Precautionary Principle, sustainable biofuel supporters should be assured that their good intentions do not have unintended consequences.[14]

According to a group of biofuels experts cited by the RSB,

> addressing indirect impacts explicitly requires: continued global research to identify and quantify links between biofuels and land use change; mechanisms to promote biofuels that do not have negative land use change impacts; mechanisms that mitigate these negative impacts but do not unduly increase transaction costs for consumers; and social safeguards at the national level, that ensure that vulnerable people are not further disadvantaged through food and energy price increases and other potential negative economic side effects.[15]

Models to predict indirect land use change are essentially economic models, as they aim to predict the macroeconomic effects of any direct changes in land use. Critics are concerned that including indirect land use change in such accounting could make biofuel feedstock producers liable for decisions made by actors they can not control, including potentially their competitors. Ultimately, how EPA certifies each combination of fuel type, feedstock, and production processes will directly affect the marketability of that fuel.

[14] Roundtable on Sustainable Biofuels, *Global Principles and Criteria for Sustainable Biofuels Production*, Version Zero, Lausanne, Switzerland, April 13, 2008, p. 4.

[15] Ibid.

Land Use Change Estimations for the Lifecycle Emissions Analysis

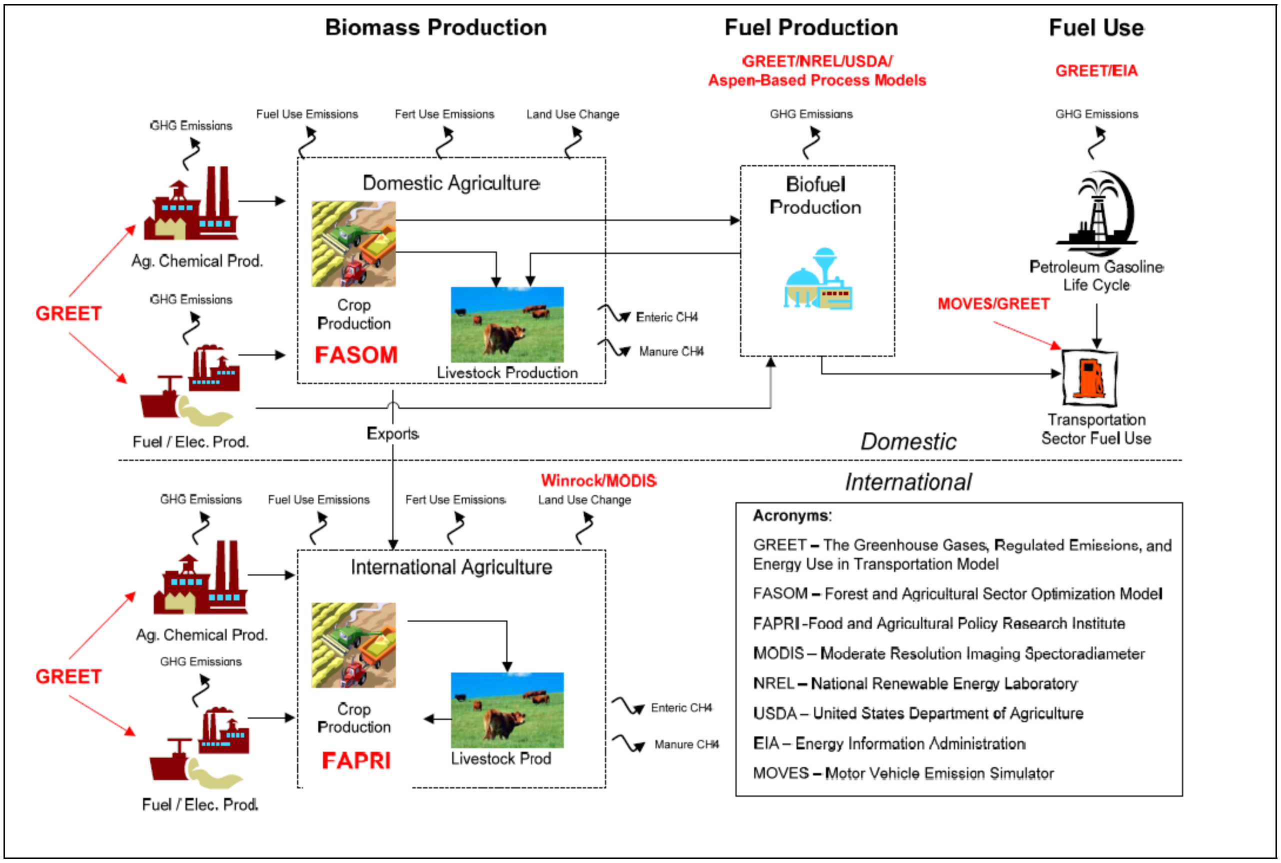
On May 26, 2009, EPA issued a Notice of Proposed Rulemaking (NPRM) to issue new RFS regulations. The NPRM included suggested methodology for a lifecycle analysis of significant greenhouse gas emissions—both direct and indirect—from the production of renewable fuels. Under the NPRM, the lifecycle analysis (LCA) was to be conducted to ensure that fuels from new biorefineries (i.e., excluding existing corn ethanol plants) achieve a 20% lifecycle greenhouse gas reduction relative to petroleum fuels, and that advanced biofuels (i.e., fuels other than corn ethanol) and cellulosic biofuels achieve at least a 50% and 60% reduction, respectively. Those renewable fuels that do not meet the specified emission reduction thresholds would not qualify for credits under the RFS. The following paragraphs summarize the major points of the methodology put forth by EPA in its Notice of Proposed Rulemaking to account for land use change in the LCA, as well as key changes between the NPRM and the final rule issued on February 3, 2010.

In the NPRM, EPA identified two criteria most likely to affect the LCA methodology: secondary agricultural sector GHG impacts from increased biofuel feedstock production, and the international impact of land use change from increased biofuel feedstock production. Land use change is considered by many to be the most pressing concern.[16] Various entities expressed an opinion about the inclusion of land use change in the LCA, and how to account for its impact. Some contended that robust methods to evaluate domestic land use change should be well understood before incorporating international land use estimates. Some also argued that it is unfair to penalize agricultural producers and biofuel production entities because of land use change that may or may not occur in a foreign territory. EPA representatives expressed on multiple occasions that, while recognizing that land use change analysis is an emerging science, they are required to proceed with implementing the law.

EPA proposed using two models, imagery data, and emission factors to estimate GHG emissions associated with land use change for the LCA (see **Figure 5**). Models are employed because resources to monitor and analyze land use change are limited. A single cohesive model or data source to estimate GHG emissions from land use change for the LCA does not exist. The models and data sources will give an assessment of the amount of land converted, the type of land converted, location for the land conversion, and GHG emissions associated with land use change (see **Table 3**). In the NPRM, models included the Forest and Agricultural Sector Optimization Model (FASOM) and the Food and Agricultural Policy Research Institute (FAPRI) modeling system. Imagery data was obtained from the Moderate Resolution Imaging Spectoradiometer (MODIS) satellite. Winrock emission factor data was proposed for use in estimating international GHG emissions from land types. In the final Rule, EPA used these models and data sources, but also used results from the Global Trade Analysis Project (GTAP) model to test the land use change results from the above models.

[16] See the "Land Use Change" and "Controversy over Biofuels Lifecycle Analysis" sections in this report for further explanation regarding the complexity of quantifying land use change for the LCA.

Figure 5. Proposed Models and Data Sources to Estimate Lifecycle Analysis GHG Emissions



Source: U.S. Environmental Protection Agency.

Table 3. Land Use Change Methodology

Key Issue	Domestic Agriculture	International Agriculture
Amount, or area, of land converted	FASOM (domestic agricultural sector model)	CARD/FAPRI (international agricultural sector model)
Location of land use changes	FASOM (regional-level)	CARD/FAPRI (country level)
Land types, or biomes, converted	FASOM (modeled interactions with cropland, pasture, CRP and forest)	MODIS Satellite Data (recent trends of land conversion between different land types)
GHG emissions from land conversion	FASOM (e.g., DAYCENT for soil carbon changes)	Winrock/IPCC

Source: U.S. Department of Agriculture (USDA) Agricultural Air Quality Task Force May 2009 Meeting. Adapted by CRS.

Notes: Forest and Agricultural Sector Optimization Model (FASOM); Center for Agricultural and Rural Development (CARD); Food and Agricultural Policy Research Institute (FAPRI) model; Moderate Resolution Imaging Spectoradiameter (MODIS); Intergovernmental Panel on Climate Change (IPCC); Daily Century model (DAYCENT).

EPA's analysis indicates that the largest release of GHG emissions from biofuel production occurs during the first few years immediately following land conversion. Lower GHG emissions are released in subsequent years of biofuel production. EPA proposed a time horizon as part of its methodology to denote the length of time emissions from land use conversion will be included in the LCA. Time horizon is defined as the time period for which biofuel production is projected to occur. Additionally, EPA proposed to discount emissions to place a value on near-term emissions, which may be estimated with more certainty than long-term emissions. In the NPRM, the suggested frameworks were a 100-year time horizon with a 2% discount rate and a 30-year time horizon with a 0% discount rate. In the final rule, EPA chose a 30-year time frame with a 0% discount rate. EPA gave two key reasons for this decision.

> There are several reasons why the 30 year time frame was chosen. The full life of a typical biofuel plant seems reasonable as a basis for the timeframe for assessing the GHG emissions impacts of a biofuel, because it provides a guideline for how long we can expect biofuels to be produced from a particular entity using a specific processing technology. Also, the 30 year time frame focuses on GHG emissions impacts that are more near term and, hence, more certain.[17]

EPA chose a 0% discount rate for many reasons, but a key reason is that the agency believes that there is a lack of consensus on the best way to apply an economic valuation (discounting) to a physical quantity, in this case (GHG) emissions, or whether such a calculation is even valid.

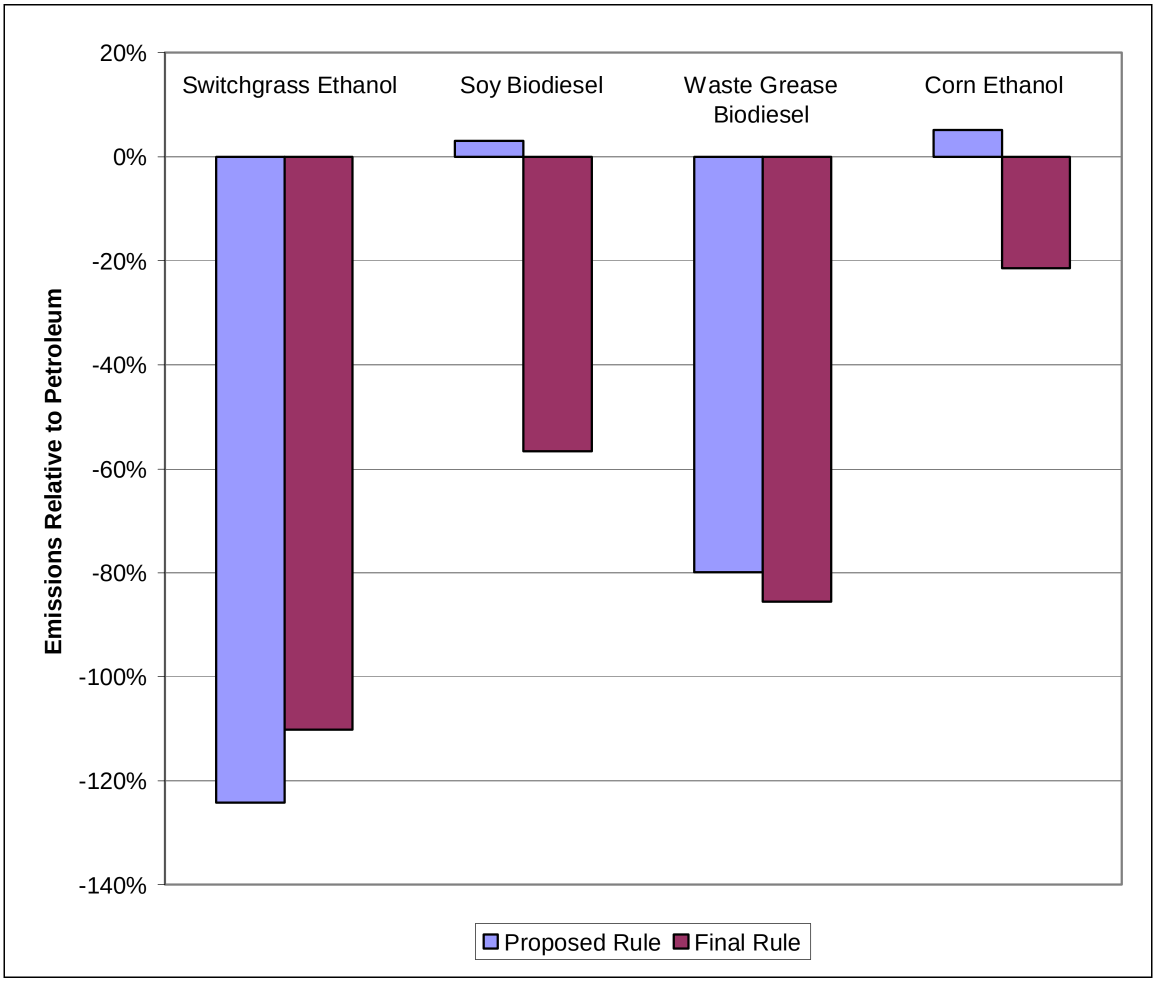
While using some of the best data and models available, EPA recognized that uncertainty exists regarding the proposed methodology to assess international GHG emissions from land use change. EPA acknowledged that a transparent and scientific analysis of the GHG emission impact of renewable fuels going forward will be further refined as additional data sources and models become available. In the NPRM, EPA sought peer review and public comment regarding:

- use of satellite data to project future type of land use changes;
- land conversion GHG emissions factors estimates EPA used for different types of land use;
- estimates of GHG emissions from foreign crop production;
- methods to account for the variable timing of GHG emissions; and
- how the several models EPA relied upon are used together to provide overall lifecycle GHG estimates.

From the peer review process and public comments, EPA concluded that various changes should be made in its lifecycle methodology between the NPRM and the final rule. These changes generally led to lower lifecycle emissions (i.e., greater emissions reductions) for most fuels (see **Figure 6**). The lower emissions estimates largely resulted from reductions in estimated emissions from international land use change. In some cases, these reductions were dramatic (see **Figure 7**). For example, the vast majority of net emissions for soy biodiesel come from international land use change (roughly 80% in the proposal and roughly 100% in the final rule).

[17] Environmental Protection Agency, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule*, EPA-HQ-OAR-2005-0161, Washington, DC, February 3, 2010, p. 241, http://epa.gov/otaq/renewablefuels/rfs2-preamble.pdf.

Figure 6. Emissions Reductions Relative to Petroleum Fuels for Selected Biofuels

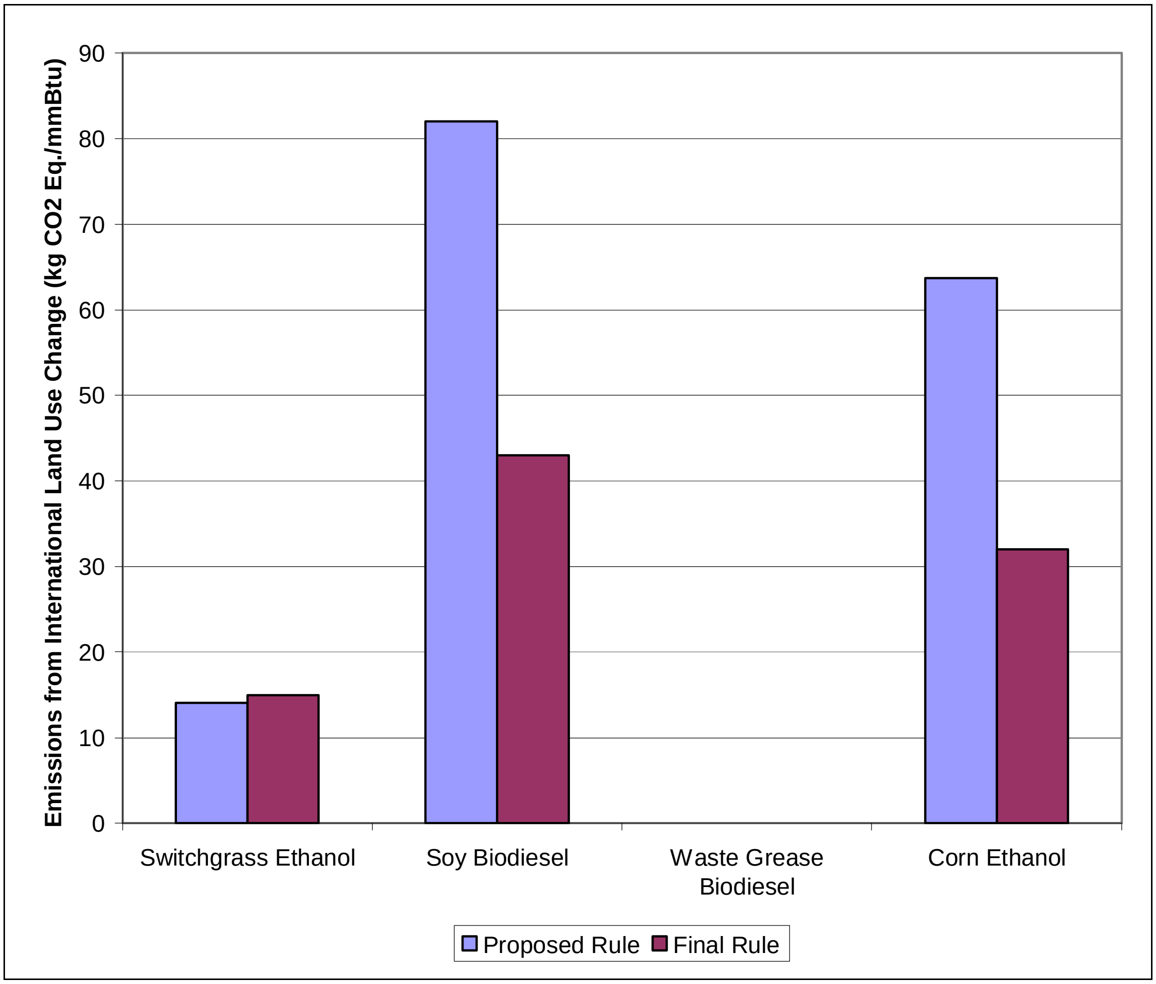


Source: CRS Analysis of Environmental Protection Agency, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule*, EPA-HQ-OAR-2005-0161, Washington, DC, February 3, 2010, pp. 255-266, http://epa.gov/otaq/renewablefuels/rfs2-preamble.pdf; and Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program," 74 *Federal Register* 24904-25143, May 26, 2009.

Notes: In the final rule as published on EPA's website on February 3, 2010, EPA concluded that corn ethanol produced from a new natural gas-fired plant results in a 21% reduction in emissions relative to gasoline (enough of a reduction to meet the threshold requirement). However, analysis of Table V.C-1 (pp. 256-266) of the final rule shows a 19% reduction (not enough to meet the threshold). According to EPA, the 19% figure is a result of a typo in the February 3 version that will be corrected before the rule is published in the *Federal Register*. E-mail from Vincent Camobreco, Environmental Protection Agency, Office of Transportation Air Quality, February 25, 2010.

The reduction in emissions greater than 100% for switchgrass ethanol is a result of additional carbon sequestration beyond that needed to offset the emissions from fuel production and use. For example, there is a large amount of carbon that would be stored in the root systems of a switchgrass plantation, biomass that would not be harvested for fuel conversion.

Figure 7. Estimated Emissions from International Land Use Change for Selected Biofuels



Source: CRS Analysis of Environmental Protection Agency, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule*, EPA-HQ-OAR-2005-0161, Washington, DC, February 3, 2010, pp. 255-266, http://epa.gov/otaq/renewablefuels/rfs2-preamble.pdf; and Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program," 74 *Federal Register* 24904-25143, May 26, 2009.

Notes: See note from **Figure 6**.

According to EPA, the diminished effect of land use change on emissions came from three key factors: (1) higher crop yields than estimated in the proposal; (2) higher efficiency of co-products such as animal feed; and (3) improved satellite data that provided better estimates of which types of land would actually be affected. For example, according to EPA:

> for corn ethanol the final rule analysis found less overall indirect land use change (less land needed), thereby improving the lifecycle GHG performance of corn ethanol. The main reasons for this decrease are:
>
> • Based on new studies that show the rate of improvement in crop yields as a function of price, crop yields are now modeled to increase in response to higher crop prices. When higher crop yields are used in the models, less land is needed domestically and globally for crops as biofuels expand.

> • New research available since the proposal indicates that distillers grains and solubles (DGS), a corn ethanol production co-product, is more efficient as an animal feed (meaning less corn is needed for animal feed) than we had assumed in the proposal. Therefore, in our analyses for the final rule, domestic corn demand and exports are not impacted as much by increased biofuel production as they were in the proposal analysis.
>
> • Improved satellite data allowed us to more finely assess the types of land converted when international land use changes occur, and this more precise assessment led to a lowering of modeled GHG impacts. Based on previous satellite data, the proposal assumed cropland expansion onto grassland would require an amount of pasture to be replaced through deforestation. For the final rulemaking analysis we incorporated improved satellite data, as well as improved economic modeling of pasture demand, and found that pasture is also likely to expand onto existing grasslands. This reduced the GHG emissions associated with an amount of land use change.[18]

Going forward, in the final rule EPA has determined that it will periodically reevaluate its LCA methodology, and that it could make changes in the future. However, these changes would only apply to biofuel plants constructed after any new rule is finalized.

> EPA will request that the National Academy of Sciences over the next two years evaluate the approach taken in this rule, the underlying science of lifecycle assessment, and in particular indirect land use change, and make recommendations for subsequent rulemakings on this subject. This new assessment could result in new determinations of threshold compliance compared to those included in this rule that would apply to future production (from plants that are constructed after each subsequent rule).[19]

California's Low Carbon Fuel Standard (LCFS)

On January 12, 2009, the state of California finalized regulations for a state low carbon fuel standard (LCFS). The LCFS requires increasing reductions in the average lifecycle emissions of most transportation fuels. The rule does not require total emissions to decrease, but the emissions intensity (emissions per unit of energy delivered) must be 10% below that of gasoline and diesel fuel by 2020. California concluded that some biofuels lead to higher emissions (i.e., lower emission reductions) than what EPA has proposed (e.g., corn ethanol). (See **Table 4**.) In other cases, the California estimates are more favorable to biofuels (e.g., waste biodiesel). This difference highlights the ongoing debate over lifecycle analysis methods.

[18] Environmental Protection Agency, *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels: Regulatory Announcement*, EPA-420-F-10-006, Washington, DC, February 2010, pp. 3-4, http://epa.gov/otaq/renewablefuels/420f10006.pdf.

[19] Ibid. p. 210.

Table 4. Lifecycle Emissions Estimates for Selected Fuels Under California's LCFS and EPA's Proposed and Final Rules for the RFS

Emissions Relative to Gasoline or Diesel Fuel

	EPA Proposal (Long-Term)	EPA Proposal (Short-Term)	EPA Final Rule	California LCFS
Time Frame and Discount Rate	**100 years, 2%**	**30 years, 0%**	**30 years, 0%**	**30 years, 0%**
Corn Ethanol (fossil fuel)	-39% to +13%	-18% to +34%	-21%	-16% to +26%
Corn Ethanol (biomass)	-47% to -39%	-26% to -18%	TBD	-19% to -2%
Sugarcane Ethanol	-44%	-26%	-61%	-39% to -23%
Switchgrass Ethanol	-128%	-124%	-110% to -82%	TBD
Soy Biodiesel	-22%	+4%	-57%	TBD
Waste Biodiesel	-80%	-80%	-86%	-88% to -83%

Source: California Air Resources Board, *Final Regulation Order*, January 12, 2010, Tables 6 and 7, http://www.arb.ca.gov/regact/2009/lcfs09/finalfro.pdf. Environmental Protection Agency, *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels*, EPA-420-F-09-024, Washington, DC, May 2009, Table 1, http://www.epa.gov/otaq/renewablefuels/420f09024.htm. Environmental Protection Agency, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule*, EPA-HQ-OAR-2005-0161, Washington, DC, February 3, 2010, pp. 255-266, http://epa.gov/otaq/renewablefuels/rfs2-preamble.pdf.

Notes: As of January 2010, EPA had not finalized the RFS rule, so the above estimates are preliminary.

Congressional Role

The 111th Congress will likely address issues surrounding biofuels lifecycle in two ways: (1) oversight of EPA's implementation of the RFS; and (2) integration of fuel lifecycle emissions into other relevant legislation.

Oversight

Definitions for various biofuels under the RFS could directly affect the supply of eligible fuels in the program. If supply is curtailed through the exclusion of certain fuels,[20] then consumer fuel prices could increase. Thus, Congress may look to determine whether any regulations promulgated by EPA adversely affect fuel supply and availability. Likewise, Congress may look to determine whether the goal of reducing greenhouse gas emissions is achieved through the lifecycle requirements of the RFS.

[20] Biofuel supply is largely associated with eligible biomass feedstocks. More than a dozen biomass definitions are included in recent legislation impacting feedstock development assistance available. For more information, see CRS Report R40529, *Biomass: Comparison of Definitions in Legislation*, by Kelsi Bracmort and Ross W. Gorte.

Related Legislation

The 111th Congress has debated legislation to address climate change and energy issues. Transportation plays a key role in both U.S. energy consumption and U.S. greenhouse gas emissions. Therefore, any policy to address these issues will almost certainly affect the implementation of the renewable fuel standard, and vice versa. Specific proposals include a carbon tax or a cap-and-trade system that would put a price on carbon emissions, promoting a switch to lower-carbon fuels;[21] and a federal low-carbon fuel standard, which would require lower carbon emissions from all transportation fuels (as opposed to just biofuels).[22] The specifics of any new legislation on fuel carbon emissions would determine how that legislation interacts with the RFS requirements. New legislation could be integrated with the RFS requirements, or it could lead to competing, or even contradictory, requirements. Therefore, the integration of the RFS with any potential climate or energy policy should be considered.

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[21] See CRS Report R40556, *Market-Based Greenhouse Gas Control: Selected Proposals in the 111th Congress*, by Jonathan L. Ramseur, Larry Parker, and Brent D. Yacobucci.

[22] For more information on a low-carbon fuel standard (LCFS), see CRS Report R40078, *A Low Carbon Fuel Standard: State and Federal Legislation and Regulations*, by Brent D. Yacobucci.