The Policy Landscape for Agricultural Bioenergy

Issue Brief 24-03 by **Emily Joiner**, **Michael Toman**, and **Suzanne Russo** — May 2024

Key Points

- Agricultural (ag) bioenergy has received financial and technical support from the Energy Title of the Farm Bill, first established in 2002. At present, however, the primary drivers of ag bioenergy are incentives in federal energy legislation (the Renewable Fuel Standard or RFS) and California legislation to reduce the greenhouse gas intensity of transportation fuels (the Low Carbon Fuel Standard or LCFS), along with policies administered by the US Environmental Protection Agency.
- The RFS creates requirements for incorporating various categories of renewable sources, including ag biofuels, into liquid transportation fuels. A complex credit program based on sales of qualifying renewable sources facilitates the achievement of those requirements. The thresholds for qualifying (20, 50, or 60 percent lower estimated lifecycle greenhouse gas intensity) are coarse-grained and thus coarsely targeted for providing incentives to reduce greenhouse gas intensity.
- The LCFS also uses a credit system to achieve targeted reductions in lifecycle greenhouse gas intensity over time. However, the emissions intensities of qualifying renewable sources are based on technology pathways, with careful assessments of actual emissions that provide incentives for reducing actual emissions intensity. Nevertheless, the measurement of reductions in emissions intensity is only as good as the baseline used for comparison—a concern that has been expressed over the calculation of negative emissions intensity for manure-derived biogas.
- There is vigorous debate about the overall reduction in greenhouse gases achieved with conventional bioethanol made from corn. Lower-carbon technologies remain costly to use at scale. Adverse environmental impacts also can arise from producing biofuels, some of which raise environmental justice concerns.

1. Introduction

Bioenergy is energy produced from biologic feedstocks processed into liquid fuel, or process heat or electricity from combustion. Various refining or processing techniques go into producing bioenergy. Agricultural bioenergy (ag bioenergy) uses agriculturally derived feedstocks, either crops grown explicitly for their use as energy or waste by-products such as manure. Biofuels and biogas are the two most common ag bioenergy fuels. Renewable biomass energy from forestry is another bioenergy source (Wear and Bartuska 2020). However, our focus in this issue brief is on ag bioenergy from farms and ranches.

Current ag bioenergy policy in the United States reflects several motivations. It creates a favorable regulatory climate for production and sale of additional products from the agricultural sector. Domestic bioenergy, including ag bioenergy, is seen as improving the security of US energy supplies by reducing imports—though we raise questions about that rationale in Section 5. A third very influential motivation is the potential for ag bioenergy to reduce carbon intensity and total emissions of greenhouse gases (GHGs) in the United States.

This issue brief provides a brief typology of bioenergy and then summarizes and discusses key elements in the nonagricultural policy landscape that have expanded production of ag bioenergy. It also highlights some important questions needing further consideration. We focus on a time frame of roughly the next 5 to 10 years, taking an agnostic view here on bigger longer-term issues such as the role for ag bioenergy vis-à-vis electricity in decarbonizing ground transportation.[1]

2. Types of Bioenergy

Biofuels include both ethanol and diesel fuels. Traditional, or conventional, ethanol relies on a distillation of food starches to fuel. Ethanol also can be made from **cellulosic feedstocks**, which results in a considerably lower lifecycle GHG intensity relative to conventional ethanol.[2] Cellulosic feedstocks can be grown on lower-quality lands, which may reduce competition between food and fuel crops on existing agricultural lands, as well as GHG emissions compared with the effects of more extensive land use to scale up food crops for ethanol production. However, cellulosic ethanol production remains low because of continuing technical hurdles.

Alternatives to petroleum-derived diesel fuels can be made from waste oils and grease from food preparation, various plant-based oils, and animal fats. **Biodiesel** is a product made from these sources through the chemical process of **transesterification**. Limited amounts of biodiesel can be blended into petroleum-based diesel fuel. **Renewable diesel** is made via processes that yield a product fully interchangeable with petroleum-based diesel. Both fuel types are ag biofuels, though raw vegetable oils and waste products from food preparation are quite different feedstocks. Oils extracted from nonfood energy crops (e.g., **jatropha**) can be another source of ag biofuels.

Biogas is a mixture of methane, CO_2, and other impurities resulting from decomposition of biomass in a low-oxygen environment. This anaerobic decomposition is found in landfills and sewage treatment plants, but the main source of ag biogas is decomposition of livestock manure. If the manure is collected and placed in a biogas digester, the resulting biogas can be collected and used. **Renewable natural gas** is biogas processed to remove impurities and is fully interchangeable with conventional (fossil) natural gas in various applications, including as a transportation fuel (compressed natural gas).

3. Federal Policy Background for Ag Bioenergy

The Energy Title of the Farm Bill was established in 2002 to accelerate production of biofuels, primarily corn-based ethanol. It is Title IX in the current Farm Bill, the Agriculture Improvement Act of 2018 (Pub. L. No. 115-334). Title IX supports, among other goals, cultivation of bioenergy feedstocks, technological processes for biofuel refinement, and research and education (CRS 2022).

Title IX programs targeted at ag biofuel production include loan guarantees and Commodity Credit Corporation payments for advanced biofuel production and payments for biomass cultivation and bioenergy conversion. The 2018 Farm Bill also established the Carbon Utilization and Biogas Education Program to support education on biodiesel and on filtering multiple sources of waste into a single stream of biogas. Other research efforts focus on stimulating production of new biofuels and other biomass derivatives.

CRS (2021b) shows the biofuel funding allocation over various years in which an energy title was included in Farm Bill authorization. The 2018 Farm Bill continued a trend of providing less mandatory program funding

1 We also do not delve into the possible role of ag bioenergy in energy sources for aviation and marine transport or ethanol derived from low-carbon hydrogen sources.

2 Lifecycle analysis (LCA) of GHGs from bio energy includes emissions from land use change (such as forest clearing), agricultural practices (N_2O and CH_4 emissions), and soil carbon sequestration benefits from biofuel crop production. It also includes emissions associated with transportation of feedstocks to refineries for biofuel production, and operation of the refining facilities (e.g., CO_2 released during feedstock fermentation to produce ethanol). The properties of the models underlying LCA results and the fundamental assumptions these models make are in dispute.

than in 2008. As explained in Section 3, the mandatory funding reduction coincided with the introduction of energy-focused legislation that led to significant expansion in US biofuel production. Title IX in the 2018 Farm Bill is largely a complementary policy focused on funding research and education.

One key energy-related policy for stimulating ag biofuel production is the Renewable Fuel Standard (RFS), established in the Energy Policy Act of 2005. The RFS subsequently was expanded in the Energy Independence and Security Act of 2007. The RFS system is administered by the US Environmental Protection Agency (EPA), which also sets requirements for incorporation of ethanol into motor fuels to improve engine performance and reduce tailpipe emissions by promoting more complete fuel combustion.

The RFS requires fuel suppliers to provide a minimum volume of total renewable fuels and of several specific categories of renewable fuels. The requirements were specified by statute through 2022, with rising obligations over time. From 2023 onward, EPA has set the volume requirements by balancing various factors listed in the statute (AFDC 2024c; EPA 2023; CRS 2023).

The categories are conventional renewable fuels (mostly corn-based ethanol) and advanced renewable fuels, which include as subcategories fuels made from cellulosic feedstocks and biomass-based diesel.[3] The specified types of biofuels qualify for inclusion in these categories only if they meet certain lifecycle emissions reduction thresholds compared with conventional petroleum fuel (gasoline or diesel). The threshold for conventional renewable fuels is a 20 percent reduction, whereas the thresholds for various categories of advanced renewable fuels are 50 or 60 percent.

In practice, rather than each supplier having to meet each of those Renewable Volume Obligations (RVOs) in its own sales, the requirements are met through a system of tradable credits. Supplies of renewable fuels covered by the RFS are assigned Renewable Identification Numbers (RINs) when they are sold into the fuels market. These numbers allow EPA to track the volumes and carbon intensities. Fuel suppliers then can purchase certificates based on the RINs as an indirect way of meeting their volumetric obligations based on their own fuel sales.

Revenues received by renewable fuel suppliers equal the sum of payments for the fuels and payments for the RIN certificates. The prices of the certificates indicate the indirect subsidies required to draw the RFS-required volumes of the covered renewable fuels into the market (AFDC 2024c, 2024d; CRS 2023; Stock 2015).[4] The requirements for conventional ethanol stopped increasing in 2015, as the demand for ethanol became constrained by EPA's current requirement of 10 percent ethanol blending into motor gasoline. Other advanced fuels have since played a larger role.

In addition to the RFS, the Inflation Reduction Act of 2022 (IRA) contains numerous production- and infrastructure-related tax breaks for biomass-based "clean energy" sources, including biogas (AFDC 2024b).[5] The IRA expands a previous tax credit (known as 45Q) for the use of carbon capture, utilization, and storage (CCUS). This has strong appeal to corn ethanol producers because the cost of capturing CO_2 from ethanol fermentation is low—an important consideration, since emissions from ethanol fermentation are estimated to be close to 1 percent of total US CO_2e emissions (Irwin 2024).[6]

3 Some renewable natural gas from farm-based manure biodigesters as well as landfills and wastewater treatment plants are included in the cellulosic category.

4 This is a highly simplified overview of what is in practice a very complex regulatory system.

5 Among those measures, the IRA continues existing tax incentives for biofuels including biodiesel through 2024, and it sets up a new clean fuel production tax credit (45Z) for 2025 (Pub. L. No. 117-169).

6 The 45Q credit is also applicable for bioenergy operations that rely on the burning of biomass, which often share feedstocks with advanced biofuels.

4. The California Low Carbon Fuel Standard

Another important driver of increased use of ag biofuels and other renewable fuels in transportation is California's Low Carbon Fuel Standard (LCFS), which began implementation in 2011 as a result of the Global Warming Solutions Act of 2006 (Pub. L. No. 109-58, Pub. L. No. 110-140, CA AB-32) and has been amended several times, with another revision pending for 2024 (CARB 2024).[7] The LCFS sets an average standard for the lifecycle carbon intensity of all covered transportation fuels, relative to conventional gasoline and diesel. Biofuels with GHG emissions lower than the compliance target for a particular year generate tradable credits that can be used by other fuel sources whose carbon intensity exceeds the standard (Yeh et al. 2021). Ethanol, biomass-derived diesel (biodiesel), and biogas have been the three greatest generators of LCFS credits since 2011 (Smith 2024a).[8] The LCFS, like the RFS, has increasing compliance targets for decreasing the GHG emissions from transportation fuels.

The use of tradable credits with a performance standard (average GHG intensity) in the LCFS illustrates an interesting aspect of this regulatory approach (Yeh et al. 2021). The tradable credits create a competitive incentive among low-carbon fuel suppliers to reduce their carbon intensity, since doing so increases the number of credits their products can obtain. The competition is based on detailed scrutiny by the regulator of actual lifecycle emissions for a variety of technology pathways used to supply the fuels to avoid undercounting emissions from some sources while failing to fully recognize the low lifecycle carbon intensity of other pathways. For example, ethanol fermenting and refining could be modified to reduce CO_2. Once the system was fully implemented, with credits benchmarked to the independent assessments of lifecycle emissions, there was a significant reduction in lifecycle carbon intensity for fuels seeking a competitive advantage. The incentive for technological improvement continues to reward low-carbon fuel suppliers that can find innovative ways to lower their carbon intensity.[9]

The LCFS includes biogas.[10] The lifecycle analysis methodology specified by the California Air Resources Board (CARB) calculates the carbon intensity of utilized biogas based on the counterfactual of no capture of the methane emissions from decomposition of the animal wastes used to produce the biogas. This implies a substantial negative carbon intensity for biogas, which makes it valuable in the LCFS for offsetting the impacts of carbon-intensive fuel options.[11] This is relevant because commercially collected and transported biogas for use as a transportation energy source is costly. Although cattle-derived biogas accounts for a significant percentage of total LCFS credits, its contribution to the transportation energy mix is minimal (Smith 2024a, 2024b).

7 While other LCFS programs exist in Oregon and Washington, **California's LCFS** has set the pace in terms of size and policy innovation.

8 The LCFS operates on top of the RFS, so energy sources that earn revenue from LCFS credits also can benefit from RINs. This complicates assessment of the LCFS's impacts. Generally, however, the result is further increases in incentives for advanced biofuel production over conventional ethanol because the former is credited with lower emissions under the California standard and the RFS.

9 An appealing political economy aspect of the performance standard is that it can reduce emissions intensity through supply-side incentives without the increases in product prices that would result from regulations or tax measures that penalize more carbon-intensive sources. The flip side is that to reduce actual emissions, not just emissions intensity, policies to shift demands toward lower-carbon alternatives are essential.

10 Unlike the LCFS credits and RINs for biofuels, which are claimed by refineries, biogas credits are awarded to agricultural producers, whose anaerobic digesters play the role of mini-refineries. In addition to LCFS credits and RINs, the California Department of Food and Agriculture offers generous subsidies for biogas digesters and other capital costs (Smith 2024a).

11 In contrast, methane captured from landfills receives no credit for avoided emissions.

Other California policies also have impacts on biofuel demand in the state.[12] California's more stringent vehicle emissions standards support advanced biofuel production (including biodiesel) through the Clean Transportation Program (CARB 2023 ; AFDC 2024a). California's Short-Lived Climate Pollutant Reduction Strategy set a 2030 state reduction goal for methane (which has a shorter residence time for trapping heat in the atmosphere, hence the strategy's reference to "short-lived") and has spurred reductions through the conversion of manure management systems to anaerobic digesters (CA SB 1383). The California Department of Food and Agriculture has provided financial assistance for the capital costs of digesters (CARB 2022). The California Energy Commission's Clean Transportation Program has supported advances in biomethane and substitutes for gasoline and diesel.

5. Impacts of the RFS and California LCFS

The impact of the RFS on the production of crop ethanol in the United States has been profound. From 2008 to 2016, there was an 8.7 percent increase in US corn cultivation and a 2.4 percent increase in US cropland production, accompanying a 60 percent increase in gallons of ethanol produced over the same period (Lark et al. 2022, 5; EIA 2024, 193). However, the impact on US GHG emissions and on other environmental conditions has been and continues to be vigorously debated. The findings by Lark et al. (2022) indicate that the RFS may have increased overall GHG emissions through 2016 (when conventional ethanol production leveled off), after accounting for land conversion to expand corn output, increased fertilizer use, and increased intensity of soil utilization. In addition, at times when ethanol blending has decreased fuel prices (because the price of gasoline is above the energy-equivalent price of ethanol), the lower fuel price would have some upward impact on vehicle distances miles traveled (Huang et al. 2013, 7).

Thus the greater focus in the RFS on advanced biofuels since 2015 likely is a plus for GHG mitigation. That view is not shared by those who emphasize the benefits to the agricultural sector and the country from crop-based ethanol under the RFS.[13]

While the RFS has succeeded in creating incentives for blending a growing quantity of ag biofuels and other renewable fuels into US gasoline and diesel supplies, the design of the program leads to several inefficiencies. Chief among them is that having RVOs for each of several covered categories of renewable fuels, as well as differences in the energy content and lifecycle carbon intensity of the fuels, leads to a wide range of RIN prices across renewable energy types. There is no reason to expect that these different prices induce cost-effective reduction of GHG emissions, such that fuel blends with lower lifecycle CO_2e emissions are priced below blends having higher lifecycle emissions, for the same amount of energy. This is not surprising in one sense, since the RFS was not designed to be a GHG mitigation policy per se; rather, it was meant to provide an incentive for utilization of various renewable fuel sources for several reasons. Nonetheless, other alternatives can induce greater cost-effectiveness in GHG mitigation, as discussed in Section 6.

Another source of inefficiency in the RFS is the coarse nature of the bins for qualifying fuels (20 percent lifecycle reduction versus 50 or 60 percent lifecycle reduction). Focusing instead on the amount of lifecycle emissions reduction per energy unit (be it 20 percent, something in between like 35 percent, or over 60 percent), as well as the cost of achieving the reduction in emissions, better correlates incentives with results. An

12 In 2022, California passed a regulation requiring all new vehicle sales to be of zero emissions vehicles by 2035 (CARB 2023). Used vehicles sales and existing internal combustion engines are not affected and therefore will still consume transportation fuels.

13 We noted in Section 1 that a major rationale for setting up the RFS was a perception that fuel sources that are produced in the United States rather than imported are more secure. In practice, however, the main concern around energy security has been the vulnerability of the US economy to petroleum market disruptions leading to price shocks, since targeted embargoes of specific countries are impossible given the integrated nature of the world oil market. When these highly integrated markets experience a disruption (a loss of supply, a sudden weather-related increase in demand, or increased concern about future disruption), the prices of *all* products rise, whether they are produced domestically or imported. The relatively small amount of ethanol used for blending implies that it provides limited protection from price shocks (Bohi and Toman 1995).

additional concern is that estimates of lifecycle emissions reductions do not adequately reflect differences in carbon intensity among production processes.

The return from sales of RIN certificates offers incentives for two types of technical innovation in the supply of renewable fuels: process innovation and product innovation. Process innovation reduces lifecycle emissions compared with those from gasoline or diesel use by cutting emissions from production of the fuels. Product innovation reduces the cost of supplying advanced renewable fuels with lower lifecycle emissions than conventional renewable fuels. The effect of the RFS on the former type of innovation is limited by the coarseness of the bins for qualifying fuels and the regulatory specification of the RVOs to be achieved.

The RFS probably has had some positive effect on product innovation. However, cellulosic ethanol production—seen at the outset of the RFS as the most promising category for future growth in biofuels—remains low because of continuing technical hurdles. Consequently, EPA has had to routinely exercise its authority to waive cellulosic fuel requirements under the RFS. A major question is when technology will advance sufficiently to make the achievement of the clear GHG reduction (and other environmental) benefits from cellulosic ethanol production commercially practical.

The design and implementation of the CA LCFS avoided many of the concerns with the RFS. In particular, the specification of technology pathways in the LCFS has induced considerable process innovation (Yeh et al. 2021). An important policy question is what would come from implementing a national version of the LCFS to replace the RFS (CRS 2021a; Huang et al. 2013). As noted, however, biogas receives quite favorable treatment in the CA LCFS, and there are signs that this will continue (Smith 2024b). Accordingly, a look at the calculation of emissions intensity for different options in the LCFS would be useful to ensure its environmental integrity and cost-effectiveness. Ultimately, policies will be needed to curb demand for total transportation energy (thus supporting increased energy efficiency and demand management) and for higher-GHG-intensity options.

6. Other Issues

Soil carbon sequestration and carbon storage in plant roots are significant considerations in minimizing lifecycle GHGs of biofuels, and they are a major factor in claims that some biofuels can achieve net carbon negativity without the introduction of carbon capture and storage technology (Kim et al. 2023; Yang and Tillman 2020; Field et al. 2020). Joiner and Toman (2023) note the high level of uncertainty about these factors. Agricultural bioenergy feedstocks differ in their yields and capabilities to increase soil carbon storage, and additional agronomic research is needed to examine the trade-offs among these and other factors (Elless et al. 2023, 58).

There has been a long-standing debate over how much corn farmers versus ethanol processors gain from the existence of policies subsidizing conventional ethanol production and blending into gasoline. Higher prices of corn and other commodity inputs increase the variable costs of production for ethanol refiners but provide economic gains to farmers. Analysis of the RFS has found significant agricultural sector benefits from the RFS attributable to increases in corn and soybean prices (Moschini et al. 2017, 1118).

Agricultural biofuels can have **adverse impacts on the environment**. At the feedstock-growing stage, the adverse impacts can involve reduced water quality from fertilizer use and ecosystem service damages from land clearing. In addition, biorefineries can produce local air pollutants. Because conventional ethanol production has led to an increase in corn output and total land area devoted to corn cultivation, these concerns are greater than if food markets had been the only driver of corn supply. Drinking water contamination and local air pollution from biorefineries raise questions about **environmental justice**.[14]

14 Similar concerns are raised about large animal feedlot operations (for a perspective on this, see Gittelson et al. 2022). These operations may present attractive opportunities for manure-derived biogas production, though this is a costly energy source whose economic success depends on especially beneficial policies. The environmental impacts and nuisance side effects also need to be considered, especially as they affect nearby disadvantaged communities.

Research and data on distributional impacts of biofuel production and Title IX funding are insufficient, making it difficult to assess equity challenges in access to biofuels production and relevant Title IX and other policy resources (Gan et al. 2019). Part of the difficulty lies in a knowledge gap regarding possibilities for engaging small and other underserved producers in opportunities to increase revenue and decrease on-farm GHG reductions through biofuel feedstock production and use of biofuels (Johnson and Butler 2015; Adjoyi and Kebede 2017). We can observe generally that corn and soy, the predominant feedstocks for conventional biofuels, come mainly from large midwestern farms with access to various types of US Department of Agriculture (USDA) assistance, whereas minority and other disadvantaged farmers tend to operate smaller farms and experience more difficulties accessing USDA programs (Joiner et al. 2023).

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