

WORKING PAPER

# Feedstock availability safeguards

*An alternative to indirect land use change accounting*

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## HIGHLIGHTS

*Biofuel policies in the United States often rely on estimates of indirect land use change included in a biofuels lifecycle analysis as a mechanism to address concerns about land use change. This approach has theoretical, practical and political shortcomings that hinder its effectiveness. The alternative is a policy with distinct incentives and safeguards that correspond to primary policy goals: (1) a lifecycle CI framework that provides concrete incentives to fuel producers to reduce pollution from fuel production processes under their control; (2) farm-based incentives designed with the particularities of agriculture in mind, to support farmers' efforts to reduce global climate pollution, improve soil health, water quality and other important outcomes; and (3) feedstock safeguards that reflect the consequences of market-wide impacts of biofuel production and align the quantity of feedstock consumption with sustainable availability.*

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February 2026

<https://files.ucs.org/2026/feedstock-availability-safeguards.pdf>

## Preface

Debate over biofuels has been at a stalemate for years. Biofuel opponents hold that expanded use of biofuels increases the demands on the global agricultural system to meet not only growing demand for food and fiber, but also fuel. This inevitably increases the footprint of agriculture at the expense of other ecosystems and is, on balance, harmful to the climate and other environmental outcomes. Biofuel advocates hold that expanded biofuel production creates economic opportunities for farmers and biofuel producers and produces sustainable substitutes for fossil fuels. They argue that environmental tradeoffs are limited and can be addressed with improved technology to increase agricultural productivity and incentives to farmers to promote improved farming practices.

My personal view, as a long-time participant in this debate, is nuanced. I agree with biofuel opponents that diverting corn and especially vegetable oil from food and feed to fuel is harmful to the climate. The recent analysis of Tzu-Hui Chen, Rich Sexton and Aaron Smith, is especially compelling, providing powerful empirical evidence that the worldwide expansion in the use of vegetable oil for fuel over the last two decades, especially in Indonesia, Brazil, the US and the EU, has accelerated deforestation for palm oil plantations in Indonesia and Malaysia, resulting in a large net increase in carbon emissions (Chen, Sexton and Smith 2025). However, I recognize that US policy has for decades supported the biofuel industry as part of a long history of promoting expanded markets for agricultural commodities. Biofuel policies have come to play a substantial role in agricultural policy and markets, and biofuel advocates argue it is unfair to reduce support for domestic biofuels produced from US crops because of deforestation in a different country. Given the political support these policies enjoy, overturning them entirely is unlikely. Thus, as a practical matter, the question confronting policy makers is not whether to support biofuels, but how to structure biofuel policies to balance competing interests and policy goals, with incentives that support positive outcomes and safeguards that limit harmful consequences.

Within this context, I argue that lifecycle carbon intensity (CI) modeling is not sufficient for the purposes the present policy moment requires, at least not on its own. Arguments over lifecycle methodology obscure what is really at stake – which is not primarily about the composition of transportation fuels, but the direction of US agriculture – and hinder transparent debate and thoughtful compromise. The alternative is a policy with distinct incentives and safeguards that correspond to primary policy goals: (1) a lifecycle CI framework to provide concrete incentives to fuel producers to reduce pollution from fuel production processes under their control; (2) farm-based incentives designed with the particularities of agriculture in mind, to support farmers' efforts to reduce global climate pollution, improve soil health, water quality and other important outcomes; and (3) feedstock safeguards that reflect the consequences of market-wide impacts of biofuel production and align the quantity of feedstock consumption with sustainable availability.

## Biofuel policies are based on Carbon Intensity

Since 2007 many biofuel policies have relied upon carbon intensity metrics based on lifecycle analysis. The Renewable Fuel Standard (RFS) amendments of the 2007 Energy Independence and Security Act established that lifecycle analysis would be used to establish eligibility for distinct categories of biofuels, which oil refiners were mandated to buy. The California Low Carbon Fuel Standard (LCFS), which came into effect in 2011, based compliance almost

entirely on fuel carbon intensity (CI), similarly based on lifecycle analysis. Both policies included estimates of indirect land use emissions (ILUC) in the CI of crop-based fuels. Subsequently, other states, including Oregon, Washington and New Mexico have adopted the California LCFS model, generally adapting the approach used by California.

In 2022 the US Congress adopted a CI based tax credit framework, first in a Sustainable Aviation Fuel Tax credit from 2023 to 2024, which was extended to other fuels in 2025 as part of the Clean Fuel Production Tax credit (called 45Z referring to the relevant section of the tax code). As enacted in 2022 these tax credits included ILUC in the CI scores, but the 45Z tax credit was amended in the 2025 H.R. 1, extending the tax credit through 2029, removing a preference for aviation fuel, and removing consideration of ILUC from the CI score used to calculate the tax credit.

## The history of CI based safeguards to address land use change

The origins of the current practice go back to the policy design of the LCFS. Renewable energy standards from the power sector decarbonization generally have not involved lifecycle analysis or carbon intensity scores but instead classified certain sources of power as renewable and required that these sources supply a growing share of power over time. This approach was modified for transportation fuels in part to address arguments that producing corn ethanol required significant fossil fuel inputs, including fertilizer used to grow corn and coal or natural gas used in the ethanol production process. Using CI scores based on lifecycle analysis allowed the LCFS to give partial credit to different alternative fuels based on the extent to which they reduced emissions compared to the fossil gasoline or diesel they replaced.

However, while the CI approach addressed some challenges about biofuels, there was still a question of how to deal with land use change. The 2007 policy analysis by Alex Farrell and Dan Sperling explained.

*One of the most challenging issues in the implementation of the LCFS is the climatic effect of land use change due to expansion of biofuel production. Because food and energy markets are global, all agricultural production contributes to the pressure to clear new land for crops. Recent scientific investigations suggest that enormous amounts of greenhouse gases can be released when lands are converted to more intensive cultivation (and also cause other adverse effects such as reduced biodiversity and changed water flows). These land use effects have been largely ignored in earlier lifecycle greenhouse gas assessments of biofuels. If biofuels are to reduce greenhouse gas emissions relative to fossil-based gasoline and diesel, then biofuels must: i) use advanced production methods (some of which are available now), ii) be derived from feedstocks grown on degraded land, or iii) be produced from wastes or residues. Land use change effects should be included in the LCFS, though cautiously at first, with the understanding that further research may change our understanding of this issue and therefore how it should be regulated.*

*(Farrell and Sperling 2007)*

Specifically, the paper recommended that California “[d]evelop a non-zero estimate of the global warming impact of direct and indirect land use change for crop-based biofuels, and use

this value for the first several years of the LCFS implementation. Participate in the development of an internationally accepted methodology for accounting for land use change, and adopt this methodology following an appropriate review.”

At the same time that California policymakers were developing the LCFS, the US Congress was debating changes to federal biofuels policy. The 2007 amendments of the RFS, initially created in 2005, enlarging the biofuel mandate from 7.5 billion gallons of ethanol to 36 billion gallons of biofuel, which was broken into several categories with eligibility based on both lifecycle CI scores and other criteria, including a restriction that corn starch ethanol could supply no more than 15 billion gallons and the largest category reserved for “cellulosic” fuels, made from agricultural or forest residues or perennial energy crops. The RFS amendments required that lifecycle carbon intensity analysis used in the RFS include “significant indirect emissions such as significant emissions from land use changes.” The US Environmental Protection Agency (EPA) developed estimates of land use change emissions as part of the rulemaking on the RFS, and revisited related matters in subsequent rulemaking processes, workshops, reports to Congress and a model comparison exercise. However, estimated land use change emissions play a less direct role in the ongoing implementation of the RFS than in the LCFS or 45Z, because the analysis informs a decision on eligibility rather than quantitatively affecting compliance value of eligible fuels.

## The theory of CI-based policies

In policies like the LCFS or 45Z that are based on CI scores, the policy implementation defines which factors are used to determine the CI score, and the outcomes of the policy are left to the market to decide. In theory, many factors can be folded into the lifecycle analysis and thus a single CI metric can accomplish many different things. A recent paper in Science Magazine titled “Climate-smart biofuel policy as a pathway to decarbonize agriculture” explained how multi-model ensembles of crop and biogeochemical models could be combined with lifecycle assessment of feedstocks, fuel production, and indirect land use change to come up with a CI score that could support beneficial outcomes in all these areas (Khanna et al. 2025). In practice, however, there are theoretical, technical, practical and political challenges to the efficient implementation of this theory.

## Theoretical challenges with CI based policies

Converting the theory of CI based biofuel incentives into practice has had mixed results. To start with, there is a core theoretical challenge about how to define the CI score. A CI score is not a well-defined physically measurable quantity, but the result of a lifecycle analysis (LCA) exercise in which decisions made about model structure, boundary conditions, inputs and assumptions can lead to dramatically different results.

In 2022 the National Academies of Science, Engineering and Medicine (NASEM 2022) committee developed a consensus report on Current Methods for Life Cycle Analyses of Low-Carbon Transportation Fuels in the United States. A core finding was that there are several types of lifecycle analysis suitable to inform different types of questions.

One type of lifecycle analysis is attributional, which assigns emissions to a product or process based on modelling choices. The Greenhouse gases, Regulated Emissions, and Energy use in

Technologies (GREET) model developed by Argonne Laboratory is a well-known example of this type of model. Attributional models assign emissions to all the inputs to a biofuel production process to determine a unique CI score for each fuel production pathway but typically do not consider indirect impacts such as land use change<sup>1</sup>. This allows each fuel producer to use data on their specific processes to develop a unique score. This approach has the advantage of providing clear and actionable incentives that influence the behavior of biofuel producers, encouraging them to take actions that will lower their CI score and thus increase the support they receive under a CI based biofuel policy.

A second type of lifecycle analysis is consequential, which considers the consequences of an action or policy, especially how they alter net global warming emissions. A consequential LCA asks how using incrementally more biofuels in US transportation fuel will affect global climate emissions, including indirect or market mediated effects. One key focus of biofuel policies has been on land use change. For example, increasing consumption of soybean oil-based renewable diesel in the United States will divert US soybean oil to fuel use that would otherwise have been exported to global food markets, leading vegetable oil consumers in importing markets to consume more palm oil to replace the soybean oil diverted from food to fuel use. Because palm oil expansion is associated with deforestation of high carbon tropical ecosystems in Indonesia and elsewhere, the emissions consequence of diverting US soybean oil from food to fuel is large (Chen, Sexton and Smith 2025). Thus, in this example, a consequential analysis assigns soybean oil-based fuels a higher CI score than would result from an assessment of direct inputs to soybean oil biofuel production under an attributional analysis.

The theoretical problem is that attributional and consequential lifecycle analyses answer different questions, and when they are added together to form in a hybrid CI score, the result does not answer any well-defined question. While both types of analysis provide policy-relevant information, their findings needn't be simply added together into a combined performance metric. Alternatively, Recommendation 9-8 from the NASEM report suggests using consequential analysis to “inform the implementation of safeguards within policies such as limits on high-risk feedstocks.”

## Technical and Practical challenges with CI based policies

In addition to the theoretical challenge, it is technically challenging to develop the analysis required to calculate emissions impacts across globally interconnected energy and agricultural markets and map changes in markets to changes in land use-change and then associate the changes in land use to changes in terrestrial carbon storage and emissions. This requires combining several distinct economic and biophysical models, which raises questions of model choice, structure, inputs, assumptions, and data quality. The results are uncertain and contested estimates of emissions, especially as background conditions change over time.

A key practical challenge with the hybrid attributional/consequential framework adopted for LCFS policies is the tension between providing a transparent and stable framework that fuel

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<sup>1</sup> While attributional models do not typically include indirect impacts, following the implementation of the LCFS, the developers of GREET added a module to GREET to analyze emissions from land use change. The model is called the Carbon Calculator for Land Use and Land Management Change from Biofuels Production and is available at <https://bioenergymodels.nrel.gov/models/17/>.

market participants need to make investments with a long-time horizon for a return, and the desire to accurately assess emissions consequences in a global and rapidly changing context.

A second practical challenge is that consequential CI metrics derived from complex interconnected models are extremely opaque. Because the scope of the analysis covers everything from global trade in agricultural commodities and energy products, to tropical deforestation and soil carbon dynamics, there are few people with the expertise to evaluate the whole analysis. This complexity creates a major barrier to meaningful participation from people with a stake in the outcome.

## Political challenges of CI based policies

Perhaps the largest barrier to the effective implementation of CI-based fuel policies is political. On the surface the CI-based policy framework delegates implementation to experts in a neutral technocratic exercise based on facts and analysis. However, lifecycle analysis methodologies are flexible, subjective and require judgement calls. This flexibility leaves tremendous discretion to agencies that will be subject to political pressure to make those choices in a manner that delivers politically preferred outcomes. Given the economic and environmental stakes for the two largest crops in the US, and strong views of environmental and conservation focused stakeholders that prioritize conservation over expanded crop production, it is naïve to imagine that policymakers will defer to the technical judgement of neutral experts in such determinations.

Policymakers and stakeholders often have strong and conflicting opinions about the quantity of particular feedstocks that are desirable to use for biofuel, but CI based policies provide only an indirect means to influence these outcomes. On one side of the debate, biofuel advocates point to low profitability of corn or soybeans and threats to export markets for soybeans as a justification to increase domestic consumption of agricultural commodities through biofuel policies. On the other side, environmental and conservation groups point to the steadily growing footprint of US cropland used to produce corn and soybeans, and increased acres of deforestation as global demand for crops grows to meet demand for both food and fuel<sup>2</sup>. The heart of this debate is not so much about lifecycle analysis but about the future of agriculture in the US and around the world.

Policy decisions on biofuels have had and will continue to have major consequences on the future of agriculture, including the footprint of agriculture and mix of crops in the US and globally. The future of agriculture deserves a more transparent debate than is possible when key decisions are buried in lifecycle CI methodologies that ostensibly evaluate transportation fuel emissions.

### Policy makers need better policy tools

The heart of the problem is that policymakers are asking a single tool, lifecycle analysis, to serve several distinct purposes. The alternative is a policy with several distinct incentives and

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<sup>2</sup> In 2025, more acres of corn were planted than at any time since 1936 and together corn and soybeans now account for 72 percent of planted acres of major field crops in the United States, up from 60 percent in 2000. Demand for ethanol has been the major driver of US corn production since 2005, and the vegetable oils and fats used to supply US bio-based diesel consumption now exceed 80 percent of total US production of oils, fats and greases.

safeguards that correspond to primary policy goals. In particular I suggest three separate elements: (1) an attributional lifecycle approach that provides concrete incentives to fuel producers to reduce pollution from fuel production processes under their control; (2) farm-based incentives designed with the particularities of agriculture in mind, to effectively support farmers efforts to reduce global climate pollution, improve soil health, water quality and other important outcomes; and (3) feedstock safeguards that reflect the consequences of market-wide impacts of biofuel production and align the quantity of feedstock consumption with sustainable availability. The remainder of this paper touches on the first two topics, which are important elements of a complete and balanced policy framework, but focuses primarily on the details of the third, which is a major sticking point to policy progress.

## **Attributional CI scores to guide biofuel producer decisions**

The track record of the California LCFS demonstrates that an attributional CI framework based on LCA tools like GREET provide a transparent and actionable set of incentives that can motivate substantial changes in fuel markets. The CI framework allows for a common compliance currency that bridges across dissimilar sectors, allowing a comprehensive policy that supports policy goals across petroleum, biofuels and electricity.

However, it is important to keep in mind the limits of attributional LCA scores. Attributional LCA is a policy tool used to encourage specific outcomes and does not offer a complete or accurate representation of outcomes in the real world. LCA methodologies involve judgement calls on which variables require measured data that is subject to verification, which variables should be based on models, and which variables will be or approximated with regional, national or global averages. There are also questions about the treatment of co-products that can have a dramatic impact on LCA results. The appropriate approach for an LCA used for a fuel policy is not an abstract academic question but is fundamentally a policy decision about the allocation of resources in the real world.

Examples from the California LCFS provide concrete illustrations. Choices on LCA structure and counterfactual scenarios shift hundreds of millions of dollars a year from California drivers buying gasoline to operators of manure digesters at dairies and swine farms. This is based on the premise that absent the opportunity to sell biomethane for transportation fuel, the methane would be released into the atmosphere (Smith 2024). But while the LCFS supports the indirect connection of manure digesters to transportation fuels, it limits the much more direct connection between different sources of crude oil and refined gasoline and diesel. Oil refiners are not able to shift to lower CI crude oils as a means of lowering the CI of their gasoline and diesel. These decisions reflect policy goals, namely that the LCFS should be used to support manure digesters but it is not intended to shift the mix of crude oils used at California refiners. These are important policy decisions that should be debated and decided primarily on the merits of the relevant outcomes rather than on nuances of LCA methodology.

## **Farm-based incentives**

Pollution associated with the production of crops used to produce biofuels is a major component of the total environmental impact of biofuel production and use and will vary depending on farming practices. Thus, it is technically reasonable that biofuel policies would include consideration of this part of the supply chain. The California LCFS does not

differentiate between different producers of commodity crops, relying instead on average values in the determination of CI scores. This decision reflects in part that influencing the actions of farmers is not a primary policy objective of California regulators<sup>3</sup>. Understandably, Midwestern states considering implementation of a clean fuel standard have prioritized the inclusion of farmers as potential sources of emissions mitigation within their policies. The federal government also proposed farm specific CI scores in provisions of the 45Z tax credit, which recognize the use of Climate Smart Agriculture (CSA) practices including no till, reduced till, cover crops, nitrogen inhibitors and fertilizer timing. If and when the proposed framework is implemented, farmers using such practices in the production of biofuel feedstocks will enter this information into a spreadsheet that estimates a reduced CI score for the feedstock. This feedstock CI will alter the CI of the resulting biofuel, potentially increasing the value of the 45Z tax credit. The premium associated with low CI feedstocks would be awarded to biofuel producers, who may share it with farmers, providing an incentive for more farmers to adopt these practices. We will learn over the next few years how well this approach works, but there are reasons to be skeptical that a policy focused on transportation fuel producers will prove an effective and/or efficient way to support pollution reduction by farmers. Key questions include whether the estimated emissions reductions are accurate and verifiable; whether soil carbon increases are durable; how much of the premium earned by biofuel producers will be passed through to farmers; and the extent to which the incentives will lead to greater adoption of CSA practices versus shuffling crops already using these practices selectively into fuel markets. However, the approach taken in 45Z is not the only way biofuel policies could be structured to support improved practices by farmers.

The nature of agricultural climate pollution and the technologies used to measure and reduce this pollution are quite different from measuring fossil energy inputs at a factory. Moreover, a fuel policy design that awards credit for CSA practices to biofuel producers gives the biofuel producers substantial market power to retain a large share of the associated value. Rather than treating CSA practices like factory inputs, clean fuel policies could devote a portion of credits to programs that directly support farmers that implement CSA practices or otherwise improve soil health and water quality. This approach has a precedent in California LCFS provisions that support hydrogen and fast charging infrastructure and direct utilities to support electrification in disadvantaged communities. These policy structures depart from a strict fuel market basis to ensure that the policy can direct resources to address key barriers to successful and equitable transportation electrification. Similarly, investments in CSA practices, soil health and water quality are key to the success of the bioeconomy, so policy makers may choose to direct resources from biofuel policies to support these outcomes.

## Feedstock safeguards in place of ILUC

Biofuel consumption has a major impact on domestic and global agricultural markets based on the quantity of different feedstock consumed to produce biofuels. However, the CI approach embeds these considerations within a complex and opaque multi-model ILUC calculation that

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<sup>3</sup> As mentioned earlier, the California LCFS includes a program that provides large incentives for manure digesters, reflecting that dairy methane mitigation is a significant policy focus of California regulators, while influencing farming practices in the production of corn and soybeans is not. California is a leading producer of dairy, but not of corn and soybeans.

is buried in a CI score together with countless other factors. The impact of biofuels on agriculture deserves a more transparent consideration than is possible now.

A recent analysis found that increasing the use of vegetable oil-based fuels globally over the last two decades increased deforestation in Indonesia and Malaysia and the associated emissions outweighed any climate benefits from replacing petroleum diesel (Chen, Sexton and Smith 2025). The extent of deforestation depends mostly on the quantity of vegetable oil used for fuel rather than which source of vegetable oil was used (palm oil, soybean oil, or some other vegetable oil) because these oils are all substitutes in the global vegetable oil market. The implication is that a safeguard to limit deforestation needs to focus mostly on how much vegetable oil-based fuel is consumed for fuel, rather than which type of vegetable oil is used. This contradicts the structure of California's LCFS which set no limits on total vegetable oil consumption, but assigns differentiated indirect land use change (ILUC) emissions to different types of vegetable oil with the hope that the resulting market signal will minimize land use change impacts<sup>4</sup>. Policymakers are also understandably reluctant to dramatically change CI scores – for example adopting extremely high ILUC scores for vegetable oil-based fuels suggested by Chen, Sexton and Smith – for fear of undermining investment made under existing policy frameworks.

The alternative is for policy makers to develop a land use safeguard that limits the quantity of vegetable oil, corn and other feedstocks that are used to produce fuel. These limits would establish the “sustainable availability” of each feedstock based on a comprehensive assessment of consequences of using these feedstocks for fuel. I use the vague term “sustainable” reflecting that an assessment of availability would not be limited to the output of a specific set of mathematical models but would reflect a value judgement about how best to use crops and agricultural land in the US and around the world. This assessment of sustainable availability would consider, for example, the consequences if the US increased or decreased the use of vegetable oil-based biofuels from its current level. This would include the impact on prices for crops and food, on trade flows and acres planted in the US and abroad, on changes in land use and deforestation and impacts on water quality, biodiversity and other factors<sup>5</sup>. Policy makers would also take into consideration other policy goals, including supporting domestic agriculture, creating economic opportunities for rural communities, and other considerations.

Based on the totality of the evidence, policy makers should make an informed decision about how much of different categories of feedstock can reasonably be used for biofuels. This decision will inevitably be at least partly political, rather than purely technical, but this is no

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<sup>4</sup>For example, the California LCFS assigns differentiated ILUC scores to specific types of feedstocks, 71.4 g CO<sub>2</sub>e/MJ to palm oil, 29.1 g CO<sub>2</sub>e/MJ to soybean oil, and 14.5 g CO<sub>2</sub>e/MJ to canola oil and zero to inedible corn oil, used cooking oil or animal fats like tallow. (CARB 2025). In 2024, in response to criticisms of growing vegetable oil based-fuel consumption, California policymakers added limits on producers of bio-based diesel fuels, restricting LCFS credit eligibility for fuels made from vegetable oil to 20 percent of each company's total production. Because these limits are imposed on individual producers rather than on the market as a whole, and because limits on credit generation reduce but do not eliminate the LCFS compliance value of vegetable oil based fuels, their impact on total vegetable oil utilization is uncertain. For more details on this topic see my recent post “Biofuel Incentives in Flux: Interactions Between Federal and California Policy” (Martin 2026).

<sup>5</sup> While this might seem like a formidable analytical task, extensive analysis of these impacts already exists within regulatory impact assessments, the triennial report on the RFS EPA makes to Congress and extensive literature in the peer reviewed record and from the stakeholder community.

change from the current situation. The decision could take the form of a schedule specifying quantities each year, or a formula or set of criteria to be evaluated by a responsible agency.

Focusing on how the quantity of biofuel feedstock should evolve over time instead of constantly relitigating lifecycle methodologies allows policy makers to prioritize stability in agricultural markets. Recent analysis offers compelling evidence that vegetable oil-based biofuels increase emissions compared to fossil diesel. Acting on this evidence in a CI-based framework would suggest assigning vegetable oil-based fuels higher CIs than petroleum fuels, which would shift the policy from encouraging their use to discouraging it. But policymakers may be reluctant to suddenly withdraw support for these fuels for fear of harming the biofuel industry and broader agricultural sector. Eliminating support would lead to stranded assets and reduce crop prices and agricultural land prices and could harm farming communities. Thus, policymakers may prefer to make gradual changes that prioritize stability. This is easier to accomplish using a policy mechanism that directly addresses the size of these markets, than using the indirect policy levers in a CI based policy.

### Hypothetical examples of a feedstock safeguard for corn

To maintain a stable land footprint of corn used for biofuels as a successor to the RFS, Congress might chose to take the 15 billion gallon limit on corn starch ethanol in the RFS as a starting point, and set the availability of corn at 5 billion bushels, which is approximately the amount of corn required to produce 15 billion gallons of ethanol. This 5-billion-bushel limit would be adjusted each year to reflect the changes in the 3-year rolling average corn yield<sup>6</sup>. In this way, the land footprint used to produce corn for biofuels would not exceed the level implied by the RFS. This approach would directly address concerns about land use change without adding an ILUC factor to the CI of corn-based fuels. Because corn used for biofuel consumed in the US has been consistently below this threshold, this limit would have no practical effect unless, and until, the use of corn for fuel expanded dramatically.

Setting corn availability consistent with stable land footprint is certainly not the only possible policy approach. Some stakeholders would argue that policy makers should reduce the acreage of corn and set aside more land for nature, as well as for mitigation of water quality problems associated with corn farming. Others would suggest that corn currently used for biofuels should instead be exported to meet growing global food demand and mitigate agricultural expansion in the tropics. Others would argue that acres of corn devoted to biofuels should be allowed to increase, favoring domestic markets for corn and increasing crop prices received by farmers.

Congress might also consider formulas or criteria aimed at agricultural market stability or food market impacts. For this purpose, the feedstock availability determination could include an annual adjustment based on the stocks-to-use ratio or the FAO food price index to allow for increased availability when there is surplus corn in the market or temporarily reduce availability to mitigate food price spikes.

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<sup>6</sup> 15 billion gallons of corn ethanol produced in 2025 would consume 5.07 billion bushels of corn at a conversion rate of 2.96 gallons per bushel (Irwin 2025). This is equivalent to 27.7 million acres and at trend yield of 183 bushels per acre (Zulauf 2025). By 2030, assuming the yield trend is unchanged, the same acreage would produce 5.33 billion bushels of corn.

Congress is an imperfect body and the decision they reach will reflect a variety of competing interests. However, debating the quantity of feedstock based on the consequences for land use, agriculture, conservation and food market impacts is a more transparent way to reach a decision than embedding the same challenges in an opaque debate about lifecycle analysis methodologies.

## Feedstock availability assessment categories

A similar process is required to make determinations for other categories of feedstock. A key policy consideration is whether to adopt broad categories that include several crops, or a larger number of narrower categories. I propose the following feedstock categories: starch, vegetable oil, secondary fats, sugar, novel oil crops (e.g. intermediate oilseeds), agricultural residues (e.g. corn stover), energy crops and woody biomass.

Separating categories allows policymakers to limit the extent to which one feedstock category can substitute for another. This has become especially relevant in recent years as imported used cooking oil and tallow displaced domestic vegetable oil in the production of bio-based diesel. By creating separate categories for vegetable oil, secondary fats and novel oil crops, and determining availability of each, competition would be allowed within the categories but there would be limits on the extent to which one category would displace another. For example, if the use of secondary fats reached its limit, biofuel producers would be motivated to switch to vegetable oil or novel oil crops that were underutilized relative to their respective limits.

As another example, agricultural residues are a promising feedstock that can increase availability without putting pressure on other markets for crops, but excessive use of these residues for energy raises concerns about risks for soil health and erosion. These factors would inform the determination of residue availability. But different factors are relevant to perennial energy crop availability, particularly land availability. So agricultural residues and energy crops should be separate categories with limits based on different criteria.

For the major current feedstocks, policy makers have a lot of information to assess risks and opportunities and make informed judgements. However, circumstances change, and the policy should include a periodic update every five years that allows for adjustments to the feedstock assessments based on a process specified in statute. For novel, developing or underutilized resources like intermediate oilseeds, energy crops or agricultural residues, the real-world impact of large-scale utilization for biofuels is speculative and uncertain. For these feedstocks, the availability assessment should be set to encourage scaleup over a decade but should not reflect a long-term best-case scenario. The assessment should be periodically reviewed and updated for the following decade every five years in light of new information. This will allow for the updated assessment to reflect real world experience rather than relying too much on speculative projections. From the perspective of the developing market, it is better to expand the availability assessment over time reflecting progress overcoming barriers than to cut an assessment that turns out to have been based on overly optimistic information or problems that developed during scaleup.

## Implementing a feedstock availability safeguard with an auction

To implement a feedstock availability safeguard, the US Department of Agriculture (USDA) should conduct a periodic auction of feedstock allowances. Allowances covering feedstock utilized for biofuel production would be denominated in units of feedstock quantity and would be required for biofuel producers to participate in federal policies supporting biofuels such as the RFS or any successor fuel standard or incentives such as the 45Z tax credit. For feedstocks that are underutilized, feedstock certificates would be issued at no cost. But as feedstock demand approaches sustainable availability the feedstock certificates auction prices would rise.

Any funds collected through the auction should be returned to US farmers, for example as payments to support practices that mitigate impacts of biofuel production. The goal of the feedstock safeguard is not to penalize farmers but to align biofuel markets with feedstock availability.

Biofuel producers rather than farmers will purchase feedstock allowances, so the feedstock safeguard will impose no restrictions on what any farmer can grow. Biofuel producers will procure feedstock allowances in order to generate compliance value, so the cost of feedstock allowances would reduce the value of the total incentive stack for a given fuel pathway. The result would be to encourage biofuel producers that have feedstock flexibility to switch to underutilized feedstocks or for obligated parties under fuel standards to switch to other compliance options.

The practical effect of the feedstock allowances is the same as the different RIN categories of the RFS or the variable compliance value assigned to fuels with different CI scores under an LCFS. It will provide a transparent and market-based variation to the policy incentive stack that aligns biofuel consumption with feedstock availability. The benefit of separating the feedstock attribute from these other policies is to allow for an enforceable safeguard on feedstock quantity that bridges across a variety of mandates or incentives that may vary over time. This is especially important as multiple markets evolve subject to different policy frameworks – including gasoline blending components, diesel blending components, drop-in replacements for diesel, jet fuel, or maritime fuel – but they all compete for the same feedstocks.

## Learning from failed experiments, building policies that work in the real world

Scientists often learn more from failed experiments than they do from successes. But to learn these lessons one must acknowledge when an experiment has failed. Efforts to safeguard against harmful land use change by fine tuning the CI scores of biofuels have encountered many challenges. Adjustments to CI scores to address land use change are uncertain, technically complex, and prone to political interference. And with multiple overlapping policies affecting markets, adjustments to CI scores have an indirect and uncertain impact on land use.

The essential question policy makers must answer is how much of the vegetable oil, corn and other resources that *can be* used to make biofuels *should be* made available for fuel use. This requires an examination of resource availability, competing uses, impacts on land use,

deforestation and food markets. Addressing this question directly and creating a policy mechanism to implement a feedstock safeguard will make biofuel policies work better while limiting unintended consequences.

A safeguard that directly addresses land use change separately from the CI scoring system allows the development of a simpler and more transparent incentive structure based on CI scores that encourage biofuel producers to minimize their emissions, and policymakers can also include specific mechanisms tailored to the needs of farmers, supporting implementation of practices that reduce emissions, improve soil health and water quality.

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## Acknowledgments

This report was made possible by the generous support of Builders Vision Philanthropy, the William and Flora Hewlett Foundation, and UCS members.

The opinions expressed herein do not necessarily reflect those of the organizations that funded the work. The Union of Concerned Scientists bears sole responsibility for the report's content.

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