Refueling Aviation in the United States

Evolution of US Sustainable Aviation Fuel Policy

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About RMI

RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Executive Summary

Sustainable aviation fuel (SAF) is one of the few technologically mature pathways to decarbonize the aviation sector — a major source of international and domestic pollution and a sector in which demand is expected to continue growing. This makes SAF production an urgent and important part of any holistic decarbonization strategy. This report seeks to summarize, explore, and understand how policy has shaped the SAF market in the United States and how the evolving policy landscape will continue to shape this growth.

SAF can be produced in a few different ways, using waste biofeedstocks, soy, or corn oils, and by synthesizing hydrogen and carbon molecules using clean electricity to create an e-fuel. SAF being produced today, albeit at low volumes, can attribute its existence, in part, to policy support at the federal and state levels in addition to growing demand from airlines and corporate consumers.

The costs of producing SAF make it an uncompetitive solution compared with conventional, carbon emissions–intensive jet fuel being used today. The picture is further complicated by the different types of policy decisions and designs that can advantage some types of SAF over others. Further, as different SAF pathways scale and attract investment for projects, it will have varying impacts on markets that compete for similar feedstocks (renewable diesel in the case of bio-based SAF; petrochemical manufacturing and other industrial decarbonization end uses in the case of power-to-liquid SAF or eSAF).

There are significant and generous federal incentives for SAF production, state low-carbon fuel programs, and SAF-specific state incentives that can all be stacked. Finally, the Renewable Fuel Standard continues to provide revenue for SAF producers to generate valuable credits under this program when their fuel is blended into conventional jet fuel supplies.

Policy certainty also drives investment certainty — a critical component for scaling the nascent SAF industry. Short-lived incentives and lack of state-level support for SAF production will discourage necessary investment and financial innovation in this space.

Importantly, not all SAF is created equal. It is critical to understand how certain policy levers will affect which kinds of SAF get deployed at scale and where financial investments are made. Power-to-liquid SAF (eSAF) represents a deep decarbonization pathway for aviation. It will require thoughtful enabling policies and guardrails, research and development support, incentive certainty, and robust market establishment to attract investment and to scale at the rate needed for decarbonizing aviation.

Introduction

Aviation accounts for 2% of global carbon emissions and 11% of US transportation-related emissions.[1] However, non-CO_2 factors — including contrails — also contribute to atmospheric warming.[2] Although their exact impact remains uncertain, a median estimate averaged over all flights finds that contrails may cause a warming effect comparable to an additional 61% of total aviation CO_2 emissions.

It is unlikely air travel will decrease as the world continues to globalize and developing economies grow. This makes it increasingly important to find decarbonization solutions for this sector. Electrification is unlikely to decarbonize long-distance commercial travel, and hydrogen fuel cell aviation faces similar efficiency and cost hurdles. Additionally, airplanes are being designed to use conventional jet fuel, and it can take a decade or longer to get new jet designs certified and placed in service.[3] Understanding that airlines are going to need to use these jets for decades to recoup costs means a solution is needed to keep aviation on track towards net zero by mid-century. That is where a "drop-in fuel" solution that supports aviation decarbonization is essential.

Sustainable aviation fuel (SAF), a low-carbon drop-in alternative to conventional jet fuel, will therefore be needed at significant scale to decarbonize a large portion of the aviation sector. From there, electrification, hydrogen, and carbon offsets can contribute to achieve full decarbonization, but SAF will be the driving aviation decarbonization technology for years to come.

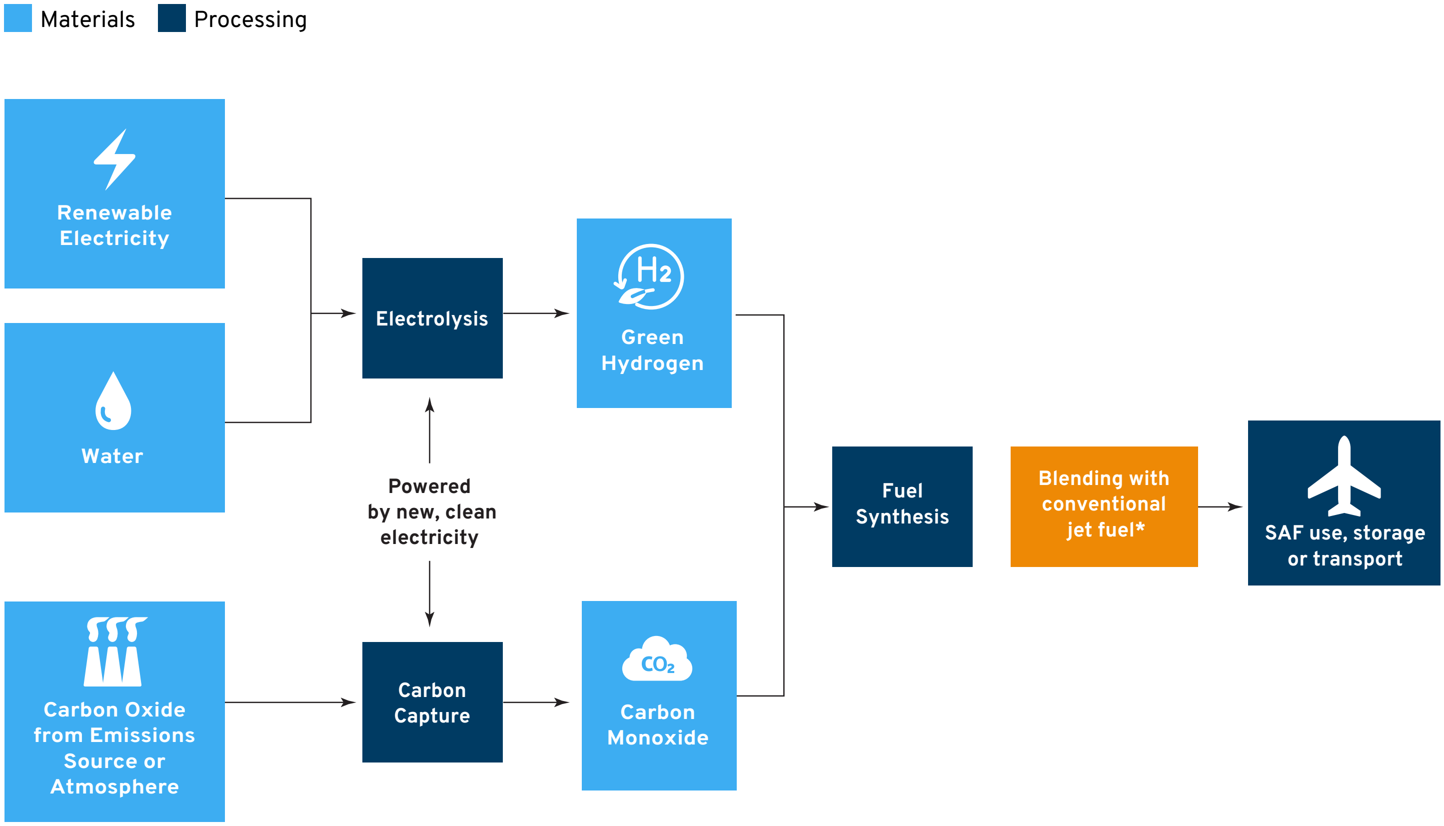
The technology requirements that would enable electrification as a decarbonization pathway are still many years away. Current battery densities for flight are less than 200 wh/kg — acceptable for short haul flights but inefficient for longer hauls. Long haul electrification would require densities in excess of 350 wh/kg, which may not be available until 2040.[4]

SAF at present is largely derived from biofeedstocks such as used cooking oil, waste fats, and similar products. Corn ethanol–based SAF (via the alcohol-to jet process) is also technically possible, but these biofeedstocks have competing uses — for example, ethanol as a gasoline blend stock. These biofeedstocks can also be used to produce renewable diesel, creating further competition. SAF and renewable diesel are often co-produced at biorefineries. SAF made from biofeedstocks is expected to reach a high of 8.9 billion gallons by mid-century, contributing to slightly less than 10% of the global aviation fuels market at that time.

Power-to-liquid SAF (eSAF), the fuel that is produced by combining hydrogen produced by renewable electricity with captured biogenic carbon (see Exhibit 1), will likely grow significantly in market share over time. Although eSAF technologies are not yet at commercial-scale readiness and face higher costs and uncertainties today, they have some advantages over bio-based SAF. These advantages include not having to compete for feedstocks (corn and soy) that could otherwise be used for food, resulting in less land use change worldwide, and appearing to enjoy policy support in the United States at both the state and federal levels going forward.

Given SAF's diverse production pathways, some existing policies will support certain technologies at the outset, while those same policies and others should be leveraged to create the enabling ecosystem for eSAF and more sustainable SAF production pathways over the long term. This report will highlight where policy gaps exist, offer lessons learned from state and federal programs, and provide a one-stop shop for the current universe of policy incentives supporting SAF production. For those interested in further understanding policies needed to support SAF deployment in the future, other reports, including *The Clean Skies for Tomorrow: Sustainable Aviation Fuel Policy Toolkit* from the World Economic Forum, provide further framing and resources.[5]

Exhibit 1 Power-to-Liquid for the Aviation Sector



* Current/temporary requirement due to aircraft engine and infrastructure limitations

RMI Graphic. Source: Airbus, https://www.airbus.com/en/newsroom/news/2021-07-power-to-liquids-explained

Federal Policy Evaluation

Between administrative actions and recent incentives created within the Inflation Reduction Act, the US government is taking significant action to support and provide market signals for rapid SAF growth and deployment.[6] Federal incentives, agency coordination, and future policy engagement will be critical levers to support the growth of a SAF market in the United States.

Sustainable Aviation Grand Challenge

Just over a decade ago, the Federal Aviation Administration (FAA) set a goal for US airlines to use 1 billion gallons of SAF annually by 2018. In 2022, domestic production reached only a small fraction of that — 15.8 million gallons — less than 0.1% of total fuel used by the industry.[7] In 2021, SAF volumes rose to 0.3% of total US supply.[8] At current rates, BloombergNEF predicts global SAF production will reach 7 billion gallons, or 5% of global jet fuel demand, by 2030.[9]

In September 2021, the Biden administration announced a new SAF Grand Challenge to inspire the dramatic increase in the production of SAF to at least 3 billion gallons/year by 2030.[10] This is a coordinated effort with participation from the Department of Energy (DOE), Department of Transportation (DOT), and the US Department of Agriculture (USDA). There are now numerous programs and funding opportunities supporting this goal, including climate-smart feedstock investments, research and development on efficient waste conversion into SAF, biofuel production grants, updated studies and data, and research on SAF blending.[11]

The Government Accountability Office (GAO) recommends that the involved federal agencies in this effort establish and incorporate performance measures into their Grand Challenge roadmap.[12]

New and ongoing funding opportunities to support SAF projects and fuel producers total $4.3 billion, which could grow with greater uptake from an uncapped tax credit for SAF production.[13]

Existing Programs

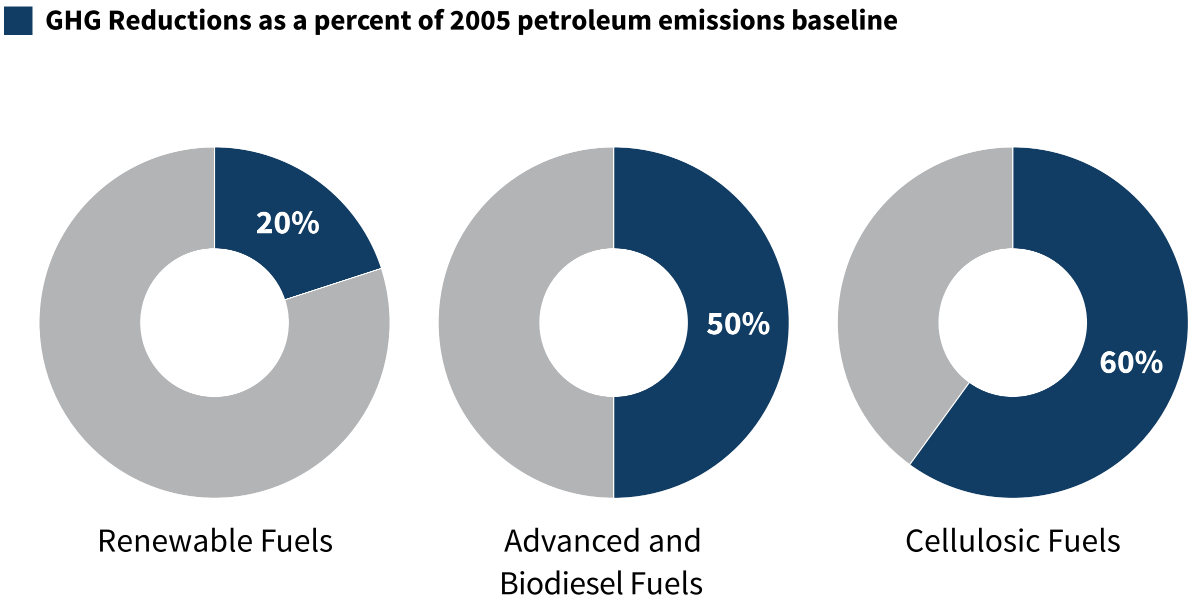
Renewable Fuel Standard (RFS)

The Renewable Fuel Standard, created by the Energy Policy Act of 2005, is a program implemented by the Environmental Protection Agency (EPA) that requires transportation fuel blenders to blend certain volumes and types of renewable fuel into their supply. This program provides a massive indirect subsidy to the biofuel industry and has long been the primary federal program supporting SAF production. However, its incentives and design have resulted in unintended climate consequences and a lack of technological development and have illuminated critical learnings for developing future clean fuel standards and policies supporting SAF production.

Each renewable fuel category in the RFS program must emit lower levels of greenhouse gases (GHGs) relative to the petroleum fuel it replaces (see Exhibit 2). For every gallon of renewable fuel blended, one Renewable Identification Number (RIN) is created that can then be retired for compliance with the EPA or sold on the market. The definition of renewable fuel under the RFS comes from a life-cycle carbon emissions analysis. Different kinds of renewable fuels generate different "types" of RINs, and each of these types has a different value on the open market. There is no requirement for the aviation sector to blend renewable fuel under the RFS; however, the program does allow SAF to generate certain high-value RINs.

Exhibit 2 RFS GHG Reductions by Fuel Type

The Renewable Fuel Standard requires different levels of greenhouse gas reduction for each fuel type.



Note: SAF qualifies under the advanced and biodiesel fuels category
RMI Graphic. Source: EPA Renewable Fuel Standard Program

Currently, the program massively incentivizes the production of corn- and soy-based fuels. For 2023, the EPA set targets of 15.25 billion gallons for corn ethanol and 2.82 billion gallons for biomass-based diesel, of which soybean oil is a major feedstock.[14] When the program was conceived, "advanced biofuels" were supposed to make up 21 billion gallons of the fuel mix by 2022.[15] These advanced biofuels include biomass-based diesel and cellulosic biofuel, derived from nonfood-based renewable feedstocks, and demonstrate emissions reductions of at least 60%.[16] Although some renewable diesel production has scaled, cellulosic biofuels have not materialized at any commercial scale, and therefore the climate benefits of the program have underwhelmed expectations.

The RVO for advanced biofuels (under which renewable diesel sits, among other fuels) is set for 7.33 billion gallons between 2023 and 2025. Of that amount, BloombergNEF predicts only 1.5 billion to 2.3 billion gallons of renewable diesel will be needed to meet the RVO, as the rest of that total will be accounted for with other existing advanced biofuel production.

Due to production buildout and other incentives available for renewable diesel production, anticipated supply of renewable diesel is set to reach 5 billion gallons by 2025. This oversupply (by as much as 3.5 billion gallons over what is needed to meet the advanced biofuel requirements under the RFS) will put downward pressure on the value of the RINs generated, which typically provide roughly 36% of total value to renewable diesel producers.[17] This value degradation may lead some producers to turn to SAF production. Federal and state incentives tilt the economic scales even further.

Lessons learned from the RFS

Over nearly two decades of the RFS, some policy goals have not come to fruition and the program now represents a subsidy to agricultural crops without driving clear decarbonization benefits and technological development. Further, credit values are misaligned with carbon reductions in fuels. Fuels with lower carbon intensity (CI) are not rewarded with higher value credits, something future fuels policies can correct with a more tech-neutral approach.

In future policies aimed at incentivizing SAF development, it will be critical to address challenges and learnings from the RFS:

1. **Support and deployment of advanced solutions:** Market-based policy should have mechanisms that support research and development and first-of-a-kind projects to allow for better fuels to enter the market as they are developed. This would help avoid disappointment like that from the advanced biofuels under the RFS, in which anticipated deep decarbonization failed to materialize.

2. **Avoid lock-in of cheaper, less effective technologies:** Market regulations could consider caps on certain biofeedstocks used to produce SAF so that the cheapest and dirtiest biofuel production pathways do not come to dominate the market. In addition, emissions measurements and validation around land use change and impacts of biofeedstock production should be carefully considered when evaluating fuel under emissions-based policies such as a low-carbon fuel standard and performance-based tax credits.

3. **Address indirect land use change (ILUC):** Another concern with the way the RFS currently operates is the way it affects and evaluates land use change. Incentives for growing corn and soy at high volumes in the United States to produce transportation fuel have created a vacuum for food crops worldwide. Other countries seeking that market opportunity have witnessed significant deforestation to increase food crop production. Removing carbon sinks in exchange for land with far less carbon sequestration potential can be difficult to quantify but is extremely important when evaluating the climate impact of biofuel incentives and fuel policies.

4. **Predict and mitigate feedstock supply shortages:** Biofeedstocks are a necessary component of renewable diesel, a popular fuel under the RFS that can be used as a drop-in fuel in diesel engines. Projections estimate that current demand for renewable diesel as a result of the RFS and other programs will create a 13-billion-pound feedstock deficit as feedstock supply is unable to keep up.[18] Given that the same feedstocks are also used to produce SAF, the tension between crops used for fuel versus food will continue to increase and can further threaten carbon sinks and biodiverse ecosystems around the globe.

Department of Transportation (DOT)

The US Department of Transportation is involved in several initiatives to promote reductions in aviation emissions. The FAA within DOT participates in the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection. This body has adopted three environmental goals, one of which is to reduce greenhouse gas emissions. The FAA was critical in establishing ICAO guidance for best operational practices to reduce fuel usage.[19]

In addition to other tools available to industry,[i] there are FAA grant programs that further support aviation decarbonization and could help promote the production and use of SAF (see Exhibit 3):

Exhibit 3 Federal Aviation Administration Programs for Aviation Decarbonization

	Fueling Aviation's Sustainable Transition through Sustainable Aviation Fuels (FAST-SAF)	Fueling Aviation's Sustainable Transition — Technology (FAST-Tech)
Funding	$244.53 million	$46.53 million
Purpose	Grants to projects that produce, transport, blend, or store SAF and projects within the Low-Emissions Aviation Technology Program	Grants to projects that design, prototype, and test low-emissions aviation technologies
Timeline	Available until September 30, 2026	Available until September 30, 2026
Cost Share	Program has 75% federal cost share, which goes up to 90% if the project entity is a small hub airport or nonhub airport	Program has 75% federal cost share, which goes up to 90% if the project entity is a small hub airport or nonhub airport

RMI Graphic. Source: Office of Environment and Energy, Federal Aviation Administration

Environmental Protection Agency

In 2020, the EPA finalized greenhouse gas emissions standards for airplanes used in commercial aviation and large business jets. This standard, which applies to new planes immediately and to in-production planes starting in 2028, matches the international airplane CO_2 standards adopted by the ICAO in 2017.[20] Further steps can be taken to ratchet up the emissions standards in the United States using the Clean Air Act authority. The Biden administration has indicated it is evaluating this option.[21]

i The FAA has also developed a model to estimate aviation emissions called the System for Assessing Aviation's Global Emissions (SAGE), which can help establish baselines and forecast technology and operational improvements. SAGE can be used to calculate fuel efficiency and has been used to support the UN Framework Convention on Climate Change efforts.

Inflation Reduction Act (IRA)

The IRA includes a bevy of tax credits that will support SAF production in different ways. Some are a direct production tax credit for creating low-carbon fuels and SAF; others will make building clean electricity capacity, producing clean hydrogen, and capturing carbon more cost effective — critical inputs for eSAF. Some of these credits can be stacked or effectively combined to maximize benefits to producers.[22]

First, the IRA includes a two-phase credit for SAF production as laid out in Exhibit 4.

Exhibit 4 **IRA Two-Phase Credit for SAF Production**

	IRA Section 40B: Sustainable Aviation Fuel Credit	IRA Section 45Z: New Clean Fuel Production Credit
Timing	In 2023 and 2024, the IRA expands the biomass-based diesel blenders tax credit (BTC) to include a specific incentive for SAF.	From 2025 to 2027, a new fuel neutral tax credit will be in place.
Compliance	SAF must reduce emissions by at least 50% compared with conventional jet fuel.	Sets a baseline emissions factor for SAF at 50 kg CO_2/million British thermal units (47.39 grams/megajoule), which the fuel must achieve to get any credit. Guidance will be needed on the emissions accounting process for both 40B and 45Z before producers will have certainty on what value of credit they can expect from production.
Value	Base credit is $1.25/gallon, with a $0.01/gallon adder for every percentage point above the 50% threshold (maximum incentive: $1.75/gallon).	$1.75/gallon for SAF multiplied by the emissions factor (determined by dividing the difference between 50 kg CO_2e/million British thermal units and the SAF emissions intensity over 50). For SAF that is zero-emissions, the emissions factor is 1 and the value of the credit is the full $1.75/gallon.

RMI Graphic. Source: H.R. 5376 — Inflation Reduction Act of 2022

The IRA also created the FAST-SAF and FAST-Tech programs mentioned above to provide incentives for SAF production, transportation, and storage and for low-emissions aviation technology design, testing, and deployment. Both programs have funding available through September 2026.

As outlined in a recent RMI blog post, the IRA provides incentives at nearly every step of the SAF supply chain (see Exhibit 5):[23]

- The Clean Electricity 48E Investment Tax Credit (ITC) or the 45Y Production Tax Credit (PTC), which subsidize the price of clean electricity at rates of up to $33/megawatt-hour for the PTC or 70% of the investment (the ITC). (This assumes the facility qualifies for the higher base rate and both the energy community and domestic content bonuses, as well as the low-income community bonus in the case of the ITC.)

- That electricity can then be routed to a hydrogen electrolyzer, the manufacture of which could be subsidized by the 48C Advanced Energy Project Tax Credit.

- The production of hydrogen could qualify for the highest tier of the 45V Clean Hydrogen PTC — $3/kg of hydrogen.

- Any extra hydrogen could be stored in a facility that receives the 48E ITC — up to 50% of the facility's investment amount. The un-stored hydrogen could then be sourced by a SAF production plant that combines it with CO_2 to make SAF.

- Additionally, the capture and sale of CO_2 are aided by the 45Q Carbon Oxide Sequestration Credit, and the construction of a SAF plant could qualify for the 48C Advanced Energy Project Tax Credit.

- The produced SAF could qualify for up to $1.75/gallon under both 45Z and its precursor 40B.

- And to off-take that SAF, the FAST-SAF and FAST-Tech programs subsidize projects that transport, store, and use SAF in commercial airplanes.

It is important to note that in this example, these credits cannot all be stacked by one entity or project, but interlock across the supply chain to support the multiple entities that must work together to create SAF (see Exhibit 6).[24]

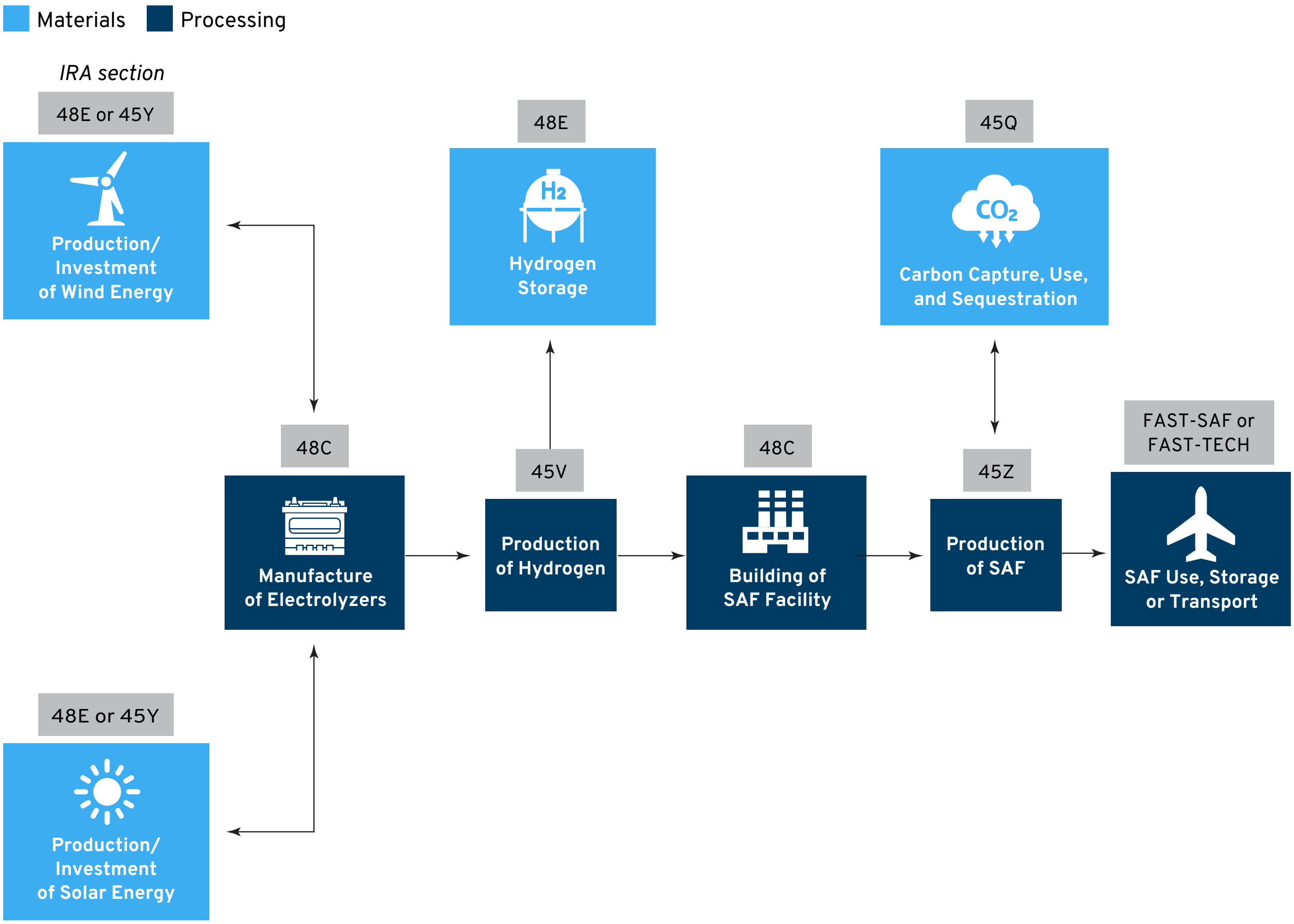
Exhibit 5 IRA Tax Credits

Credit Name	Tax Code	CBO Amount	Uncapped?	Direct pay?	Transferability?
Clean Hydrogen Production Tax Credit	45V	$9 billion	Yes	Yes**	Yes
Sustainable Aviation Fuel Credit	40B	$98 million	Yes	No	No
Clean Fuel Production Credit	45Z	$3 billion	Yes	Yes*	Yes
Credit for Carbon Oxide Sequestration	45Q	$3 billion	Yes	Yes**	Yes
Clean Electricity Investment Tax Credit	48E	$11 billion	Yes	Yes*	Yes
Clean Electricity Production Tax Credit	45Y	$51 billion	Yes	Yes*	Yes
Advanced Energy Project Credit	48C	$10 billion	No	Yes*	Yes
Advanced Manufacturing Production Credit	45X	$40 billion	Yes	Yes**	Yes
Advanced Industrial Facilities Deployment Program	-	$12 billion	No	-	-

*Applies to tax-exempt organizations.
** Applies to non-tax-exempt organizations, but only part of the length of the credit.

RMI Graphic. Source: H.R. 5376 — Inflation Reduction Act of 2022

Exhibit 6 **SAF Project Credit Supply Chain Interlock Illustration**



RMI Graphic. Source: H.R. 5376 — Inflation Reduction Act of 2022

Legislative Activity

Congress has been playing a more active role in SAF policy and clean fuels legislation in recent years. A proposed SAF tax credit eventually became what was included in the IRA. Must-pass bills (legislation typically passed on a regular cadence to reauthorize key national programs) can be used as vehicles to include new programs and policy supporting SAF.

Sustainable Aviation Fuel Act (H.R. 2747)

On April 20, 2023, US Rep. Julia Brownley of California introduced the Sustainable Aviation Fuel Act.[25] This bill would establish a national goal to achieve a net 35% reduction in emissions from flights by 2035 and reach net-zero emissions by 2050.

The bill would further require the EPA to establish a low-carbon fuel standard for aviation fuels (more on low-carbon fuel standards later in this report). The EPA would be required to set annual targets that would reduce emissions from aviation fuel by at least 20% by 2030 and 50% by 2050. The bill would require the government to purchase SAF for 10% of Department of Defense operations; require DOT to administer a grant program supporting the production, transportation, blending, and storage of SAF; and establish SAF and aviation decarbonization research programs.

Finally, the legislation would establish a federal tax credit for SAF production facilities through 2036. This bill has been referred to multiple committees in the House, but as of writing has not received any hearings or further action.

Federal Aviation Administration reauthorization

On July 20, 2023, the House passed the FAA reauthorization bill. The Senate has its own version which went through the committee process on June 15 and awaits passage by the whole body. The original FAA funding deadline of September 30 has been extended twice with short-term spending bills. The current funding deadline is March 8, 2024.

FAA reauthorization is typically a bipartisan process; this year is no different. Given these dynamics, it is unlikely that this bill will present an opportunity to move the needle on SAF and climate-focused initiatives. In future years, FAA reauthorization may be the right vehicle to re-up funding for FAA programs or introduce policies that support SAF production and adoption at airports.

Farm Bill reauthorization

The Farm Bill is our nation's agriculture, nutrition, rural energy, and forestry funding and authorization bill. It requires reauthorization every five years, and although the previous Farm Bill expired on October 1, 2023, Congress extended most of the programs for another year as debates on longer-term reauthorization continue.[26]

The Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (Section 9003) at USDA can be reformed, authorized at higher levels of funding, or otherwise adjusted to further support SAF development.[27] As with FAA reauthorization, the Farm Bill typically requires bipartisan cooperation and negotiations for the bill are well under way, which makes changes to this version difficult to pursue at this point. However, reauthorization occurs every five years, which presents a good opportunity to begin development and socialization of these ideas in the next few years.

Typically, new programs and new authorizations face a headwind when first being considered for the Farm Bill. The next few years present an opportunity for legislative proposal generation, member education, and coalition building. Engaging early with key members on the agriculture committees in both chambers and committee staff will help ensure that these ideas are considered when work begins on the next Farm Bill. The think tank Third Way has proposed updates and engagement on this program to support SAF development.[28]

Possibility for a federal low-carbon fuel standard

Congressional proposals

US Rep. Paul Tonko of New York is leading the conversation around a federal low-carbon fuel standard (LCFS) policy. Outside of a SAF production tax credit extension, this kind of policy would have the greatest impact on scaling a national SAF industry.

Tonko has drafted a bill, still in draft form, that would create different CI reduction pathways for aviation, maritime shipping, and road transportation. Interestingly, the proposal includes a mechanism to plateau, repurpose, and phase out the RFS. The current version of the legislative proposal would replace the RFS and its obligations with a temporary renewable aviation fuel mandate. This would provide certainty for biofuel producers that their product will have a home within aviation fuel production for a set number of years; however, after that point the CI requirements of the LCFS would be the driving market signal for SAF production.

The discussion draft shared with stakeholders in June 2023 left several substantive issues unresolved, including final CI reduction target and timeline for each sector, whether credits will be traded between sectors, CI modeling and assessment, and what kind of emissions accounting system is used to measure land use change impacts.

Some argue that the authority to create an aviation-specific LCFS already exists within the FAA.[29]

Policy Gaps

RMI sees eSAF is a crucial opportunity to support long-term aviation decarbonization. Success for this pathway will rely on a durable supply of accredited clean hydrogen and an affordable and accessible supply of carbon — from biogenic, non-biogenic, or direct air capture sources. Enabling policy with a long view on these markets will be critical to shaping the success of SAF and a truly decarbonized aviation sector.

Sustainable supply incentives

Hydrogen

The 45V clean hydrogen production tax credit provides a significant boost in the near term to clean hydrogen production. The goals of this incentive and the advocacy around its implementation are centered on jumpstarting a durable clean hydrogen market. However, there is risk that the credit will create a boom and bust within the clean hydrogen industry and some projects could shutter after the credit expires. Future policy could include expanding, contracting, or reforming this kind of production tax credit. It could also include a more robust investment tax credit (which does currently exist but is not perceived to be as lucrative as the production tax credit) for clean hydrogen production. Electrolyzer manufacturing could also be the focus of future policy incentives — and this could be especially valuable as the power grid decarbonizes and the question of emissions accounting on the grid becomes less contentious.

Carbon as a feedstock

Carbon will be a necessary feedstock to produce eSAF and other alternative fuels such as e-methanol for maritime shipping. Currently, the market for carbon, usually sourced as CO_2 molecules, is fairly niche: the largest end uses are enhanced oil recovery, the beverage industry, chemical manufacturing, and medical applications.

CO_2 today comes from various sources, including CO_2 captured at industrial facilities and mined CO_2, found in geological deposits. In the future, feedstock CO_2 for SAF and other alternative fuels will need to come from a source that either reduces emissions through point-source capture of biogenic CO_2 or through the removal of CO_2 directly from the atmosphere or upper hydrosphere using synthetic removal methods such as direct air capture (see *Consider the Source: Understanding the Different Types of* CO_2 for a description of different types of CO_2).

The use of biogenic or removed CO_2 is critical because the CO_2 is sourced from the existing natural carbon cycle. If eSAF is produced with fossil CO_2 (even if it is captured at a point source), it is effectively a conduit for moving more CO_2 from underground and into the atmosphere and will not serve the purpose of decarbonizing aviation or the global economy.

Consider the Source: Understanding the Different Types of CO_2

Although one ton of CO_2 is chemically identical to every other ton, the origin of CO_2 has implications for its impact on warming and atmospheric concentrations.

Fossil CO_2: Emitted from combustion of fossil fuels, which results in new CO_2 entering the carbon cycle

Biogenic CO_2: Emitted from combustion of biomass, which is part of the natural carbon cycle and therefore does not add to the total amount of CO_2 in the carbon cycle

Removed CO_2: CO_2 removed directly from the atmosphere or upper hydrosphere

Regardless of the type of CO_2, the consideration of the full life-cycle emissions associated with the CO_2 is critical.

The market for feedstock CO_2 will face several challenges as the industry scales:

Infrastructure constraints. Pipeline infrastructure for moving CO_2 is relatively concentrated in specific markets, especially the Gulf Coast. As CO_2 is increasingly captured for utilization and permanent storage, significant infrastructure investments will be needed to meet demand and provide supply at scale around the country.

Planning and permitting timelines. In most cases, states retain authority over siting of CO_2 pipelines while the federal Pipelines and Hazardous Materials Safety Administration (PHMSA) has authority over pipeline safety.[30] Deploying new pipeline infrastructure safely is likely to be slow given the need for significant cross-state coordination and the fact that PHMSA is rightly revising its safety standards after a pipeline failure in 2020 in Satartia, Mississippi.[31] A draft of this rule is not expected until early 2024, but progress may be affected by the current vacancy at the top of PHMSA.[32]

Further delays at the federal level could affect the ability for this technology to scale as states like California prohibit carbon dioxide from flowing through new pipelines until the federal safety regulations are finished.[33]

Geographic disconnect between supply and demand. Infrastructure constraints are likely to limit movement of eSAF from places with production capacity to places with demand — particularly to progressive states with more ambitious climate goals and investments but lacking in production capacity.

The IRA and the Bipartisan Infrastructure Law (2021) include significant funding to support the full carbon management value chain. These include the 45Q tax credit for carbon capture, utilization, and storage; multiple grant and finance mechanisms under the Carbon Dioxide Transportation Infrastructure Finance and Innovation Program; and demand-side support for governments and utilities to procure products that use CO_2.

Book and claim

Although the government funding described above will inject significant capital into developing the carbon management value chain, infrastructure deployment will take time. In the interim, market infrastructure such as a book-and-claim system can help ensure that eSAF producers can still benefit from demand that is physically separated from production.

Book-and-claim systems can help to track and trace environmental attributes as they are separated from the physical product from which they are derived. These systems may be critical for hydrogen production, carbon capture and utilization, and SAF markets.

The Sustainable Aviation Buyers Alliance is one example of a collaborative initiative developing an effective book-and-claim system for SAF that ensures verification and prevents double claims — critical to preventing degradation of the quality of these attributes.[34]

If done appropriately, book-and-claim systems can unlock a new revenue source from corporate end users of value chains to help cover the green premium of SAF in exchange for the legitimate claim of the associated environmental benefits. Given that this is a market-based, voluntary approach, it is critical to ensure accurate and transparent traceability, additionality, accounting, and reporting for this system to realize the potential benefits.

States that enable and participate in responsible book-and-claim systems can further unlock investment in SAF deployment.

Safety

Transportation of hydrogen, carbon, and SAF will all require increased infrastructure capacity and safety regulations that may not exist at the smaller scales of transport currently used. Cooperation between federal and state entities responsible for safe production, storage, and transportation will be critical to scaling this industry.

Nascent industries, such as SAF, cannot afford the perception or reality of safety problems along the supply chain. Safe and consistent supply of fuel inputs and the fuel itself will ensure that public perception and project costs continue to enable growth of the industry, especially in the early years.

Infrastructure planning

RMI is working on a North American Hydrogen Backbone project to deliver a vision of the required infrastructure needed to enable hydrogen-based decarbonization to become a reality.[35] Based largely on the work done in creating the European Hydrogen Backbone, this work will create a foundational vision for hydrogen infrastructure needs, create ecosystem alignment on pathways for development, and reduce supply chain uncertainty and build demand-side confidence. This proposed national infrastructure network plan for hydrogen, in addition to the creation of the clean hydrogen hub program, will support more rapid deployment and market certainty in the creation and supply of clean hydrogen for end-users, such as eSAF. Policy solutions aren't included in the initial scope of this work, but they will come into focus after the initial landscaping and consensus-building work is completed.

Preventing biofuel lock-in

The RFS, described above, offers lessons on biofuel lock-in and illustrates the risk of a fuel policy that can adjust volume obligations and provide alternative compliance pathways to reduce burdens on obligated parties. The program's intended decarbonization targets have been undermined by this dynamic, and the overproduction of corn ethanol has led to land use changes and emissions increases as discussed above.[36]

Currently, SAF is largely produced with biofeedstocks such as waste fats, tallow, and used cooking oil. With new incentives and increasing demand, it is possible that more biofeedstocks like corn ethanol and soybean oil will be diverted to SAF production. If the long-term policy goal of existing and future SAF incentives is to encourage projects making SAF from waste biofeedstocks and power-to-liquid processes that combine clean hydrogen and captured carbon, then it is critical to consider the suite of policies necessary to shape the market for the long run. The existence of IRA tax incentives that provide greater value for fuels with lower relative CI scores does not guarantee that the necessary infrastructure and technological developments will come to fruition to support the processes with greatest environmental benefits.

Permitting

Federal opportunities to reform permitting and siting may be one of the few bipartisan opportunities for progress in the clean energy space in the next couple of legislative sessions. The politics of permitting are complicated as it touches on clean energy deployment, legacy oil and gas infrastructure, tribal and state sovereignty, community safety, and historic discrimination in permitting and siting decisions. It will be critical to understand the political landscape and navigate these challenges to support the scaling of SAF production.

On June 3, 2023, President Joe Biden signed into law the Fiscal Responsibility Act of 2023 to raise the federal debt limit. Included in this bill were several reforms to federal permitting and environmental review, including clarifying the scope of the National Environmental Policy Act (NEPA), adding new NEPA provisions meant to provide more streamlined processes, authorizing a study on interregional transfer capabilities between neighboring transmission planning regions, and streamlining permitting for energy storage.[37] These reforms are modest compared with the scale of policy and reform that is needed to enable significant new electricity and transmission capacity required to meet growing industrial demand and support eSAF project deployment.

At the next opportunity to pass permitting reform legislation, it will be critical to provide greater administrative capacity for those who conduct environmental reviews.

Environmental justice and community engagement

Community engagement and addressing environmental justice concerns are critical to successful low-carbon fuel policy and incentives at the federal level. Policies promoting SAF will undoubtedly face concerns and questions from community groups given the industrial capacity required to produce SAF and the transportation infrastructure buildout necessary to achieve eSAF at scale. As evidenced by hurdles that states face in passing their own LCFSs and the engagement from community groups in California's LCFS reform work, making sure concerns and questions are addressed at the outset can be critical to the success and durability of any policy.

Care and consideration should be taken to make sure that LCFSs, which will be leveraged to support SAF deployment, are not regressive policies shifting cost burdens onto low-income populations. Book-and-claim systems should also be calibrated to reduce impacts of poor air quality in the areas where products like SAF are produced, especially when that project purchases environmental attributes from elsewhere to receive accreditation as a clean production facility.

State Policy Evaluation

SAF has not been produced at volumes close to meeting nationwide targets, nor has it had a significant impact in decarbonizing air travel. However, state policies combined with, and complementing, federal policy can help support project economics and accelerate SAF production. One of the most promising policies at the state level is the low-carbon fuel standard.

Low-Carbon Fuel Standards

A low-carbon fuel standard is a program designed to reduce transportation-based greenhouse gas emissions and air pollution using a market-based mechanism that caps the CI of fuels.[38]

By placing an annually decreasing cap on the CI of transportation fuels, the LCFS incentivizes the use of lower-carbon fuels like biofuels, hydrogen, and electricity. Through a market-based credit system, fuel producers and importers earn credits for exceeding the standards (achieving a lower-than-required CI) and sell them to regulated parties unable to meet the cap. This creates a financial incentive to produce and use cleaner fuels. On the other hand, sellers of fuel that is more carbon intensive than the target generate deficits and must purchase credits from clean fuel producers to comply with the program.

What are the key elements of an LCFS?

Baseline year

Every state policy chooses a different baseline year to compare the CI of fuels produced in the present. A later baseline year may represent a slightly more ambitious policy because it likely includes a more decarbonized fuel mix as electrification and renewable diesel have entered the fuel markets.

CI reduction schedule

Programs can decide how quickly to ramp down the CI of the fuel mix. This decision is based on expectations of technology development, state climate goals, cost projections, and balancing credit and fuel prices.

Credit price management

Since an LCFS is a market-based policy, the markets determine the price of a credit generated and traded to comply with the policy. However, policymakers will likely want to ensure that credits don’t become too cheap, making it not worth investing in decarbonized fuels, or too expensive, making it burdensome for obligated parties to comply and potentially creating an inflationary impact on retail gasoline prices.

There are options to cap credit prices (and to establish price floors), allocate quantities of credits distributed to certain pathways, and accelerate the CI schedule, among other mechanisms to manage credit volume and price within an LCFS.

Who currently has an LCFS?

California, Oregon, and Washington state have LCFS programs in place. In Canada, British Columbia has an LCFS.

Who is considering an LCFS?

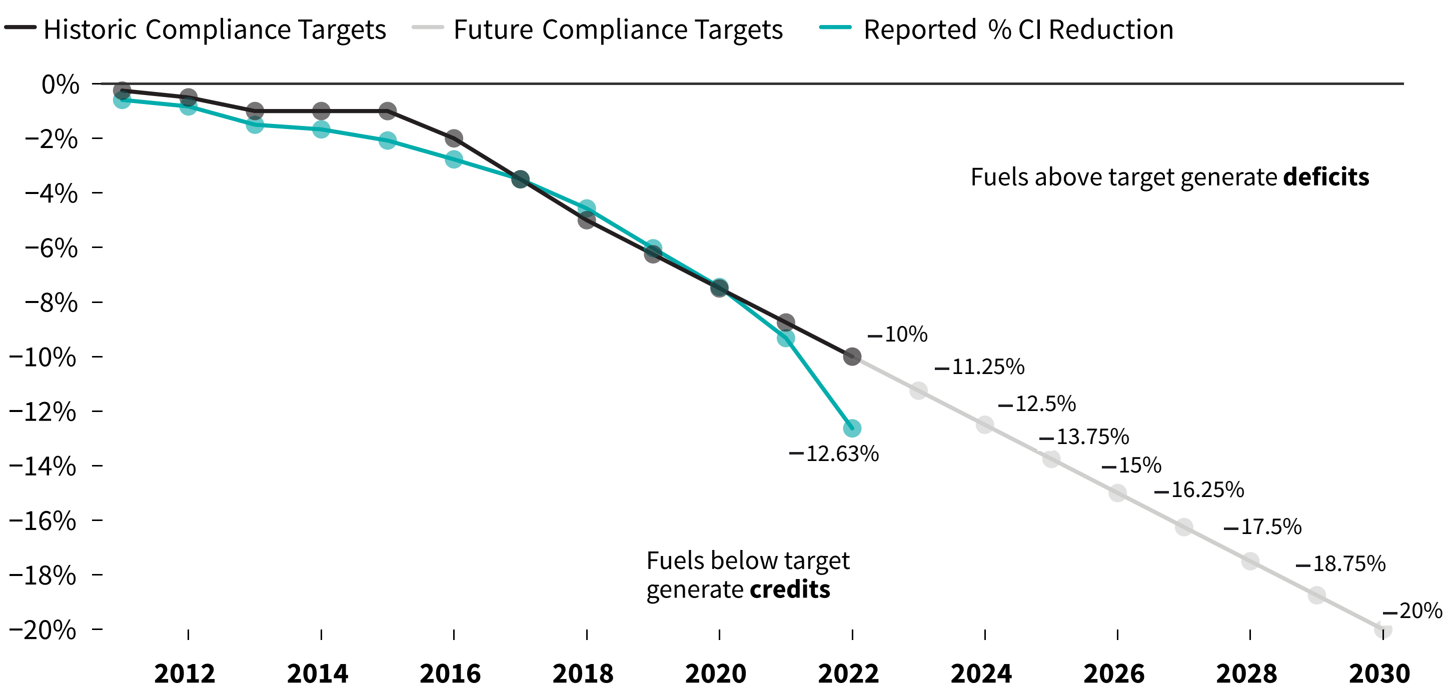
Colorado, Hawaii, Illinois, Massachusetts, Michigan, Minnesota, Nebraska, New Jersey, New Mexico, New York, Ohio, Pennsylvania, and Vermont have all either attempted to pass an LCFS policy, have explored the possibility of passing one, or have seen significant advocacy in the state for one.

California's LCFS remains the leading example of state clean fuels policy

First adopted in 2009 by the California Air Resources Board (CARB), California's LCFS is the most mature program in the country and continues to change as technology advances and new challenges arise. The California program provides a good model to study and understand as states pursue their own LCFS programs.

The CI benchmarks for LCFS fuels are an annually declining standard, defined as a percentage reduction from the average CI of gasoline and diesel fuel in 2010. Carbon dioxide, carbon monoxide, methane, nitrogen oxides (NOx), and volatile organic compounds (VOCs) are all included in a fuel's overall emissions intensity. Rulemaking in 2018 set the LCFS reduction goals to 20% below a 2010 baseline by 2030, as represented in Exhibit 7. The graph also shows the actual CI reduction reported, accelerating beyond what is required by the program.

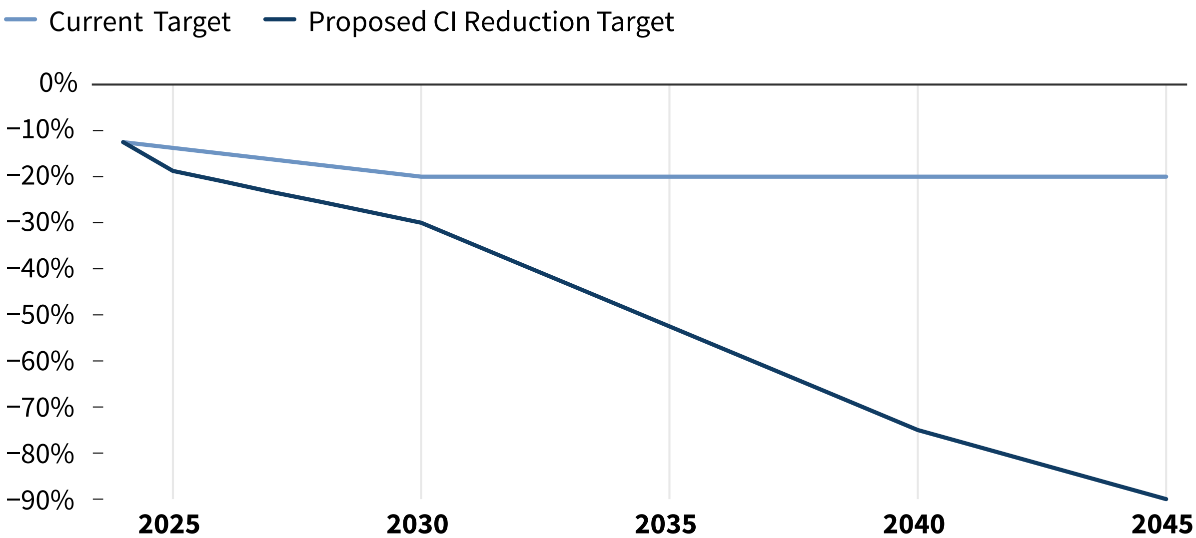
Exhibit 7 California LCFS Targets and Historic Performance



RMI Graphic. Source: California Air Resources Board, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard

On December 19, 2023, CARB released proposed amendments to the California LCFS which included a tightening of these targets — 30% CI reduction from 2010 levels by 2030 and 90% CI reduction from 2010 levels by 2045. These proposed rules have not been fully approved yet, but they are likely to take effect in spring of 2024.[39] Exhibit 8 shows how the proposed rules would affect CI targets compared with targets set by current regulations.

Exhibit 8 Impacts of Proposed California LCFS Rulemaking on Emissions Reduction Goals from 2024 to 2045



RMI Graphic. Source: CARB Proposed Low Carbon Fuel Standard Amendments

Jet fuel and SAF under the California LCFS

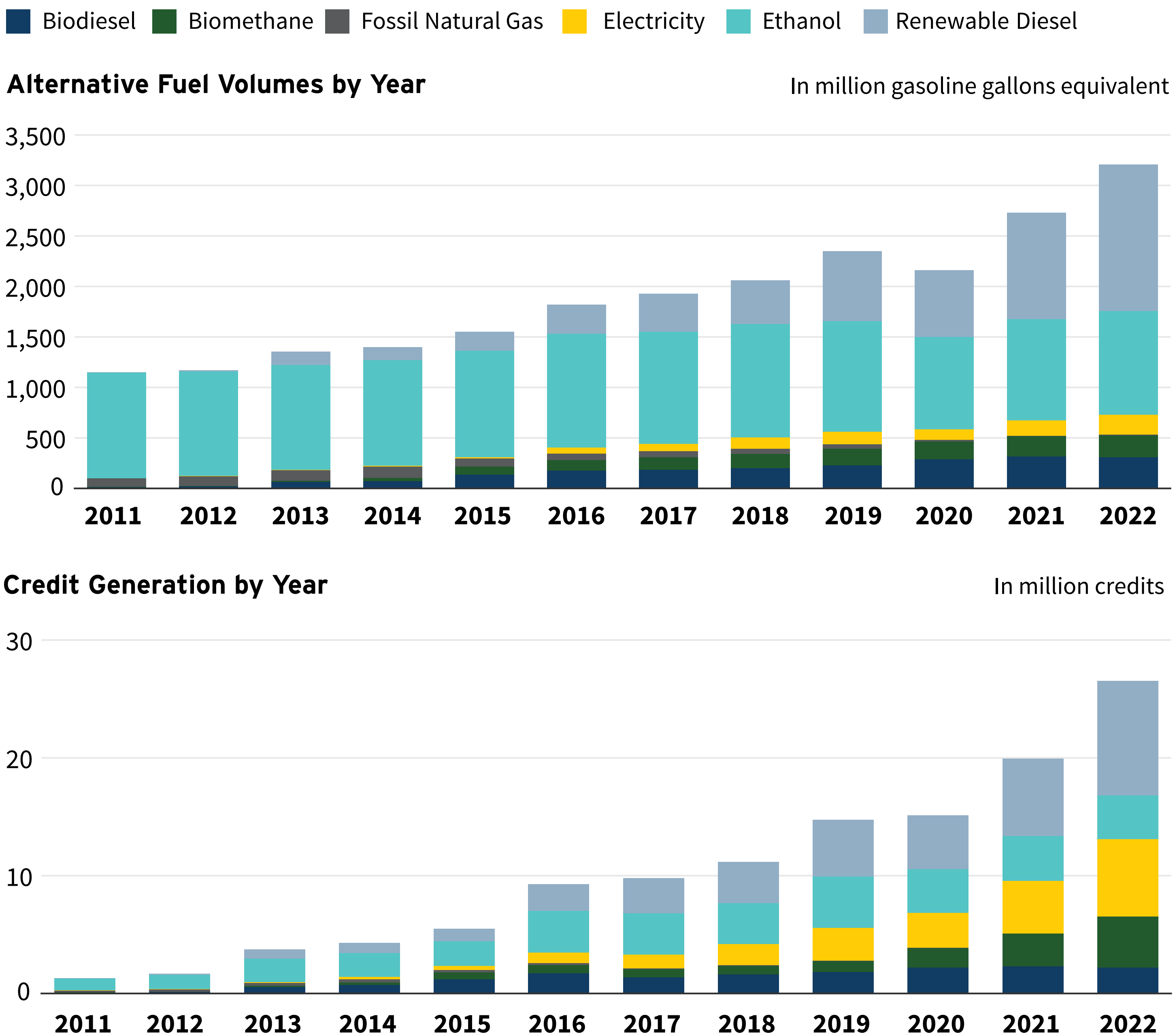
Originally, conventional jet fuel was excluded from participating under the LCFS. In 2018, California amended the program to allow producers of alternative jet fuel, which includes SAF, to voluntarily "opt in" to the LCFS. This allows SAF producers to generate credits under the program and sell them to other obligated parties for revenue, while no jet fuel refiners are required to blend any cleaner fuel into their supply.[40]

One of the most notable changes recommended by the December 2023 proposed rulemaking is the elimination of the jet fuel exemption from LCFS for intrastate flights by 2028. If passed, this would mean that all flights that take off and land in California would be potential deficit generators under the LCFS system. In California, 10% of all jet fuel is consumed by intrastate flights, so this policy change is more significant than if it were implemented in smaller states.[41]

Part of the reason SAF has not delivered large volumes (see Exhibit 9) despite the opportunity for revenue under the program is the comparative advantage of producing renewable diesel (RD), which competes with SAF for feedstocks. Given that jet fuel is currently not an obligated fuel under the program and that diesel refiners are required to comply with the program, it is not surprising that RD production continues to outpace SAF production. Additionally, the financial incentives included in existing policy have historically made RD production a better value proposition than SAF. If implemented, the new rulemaking may succeed in pulling some feedstocks back toward the SAF supply chain, but how much remains to be seen.

Currently, SAF remains a minor contributor of credits to the market. In Exhibit 9, SAF doesn't even show up because it represents less than 1% of the credit market. As of August 2023, AltAir LLC, which was acquired by World Energy in 2018, is the only entity that has participated in the LCFS Alternative Jet Fuel pathway.[ii]

Exhibit 9 Fuel Volumes and Credits Generated Under California LCFS



RMI Graphic. Source: CARB LCFS Data Dashboard

ii In the most recent **"Current Pathways" spreadsheet** from CARB, the certified CI score is 19.51. Currently, production of SAF is dominated by the most technologically mature pathway, hydroprocessed esters and fatty acids (HEFA), with animal tallow as the primary feedstock.

SAF vs. renewable diesel: A turning of the tides?

The most technologically mature pathway for SAF involves the use of hydroprocessed esters and fatty acids (HEFA), with animal tallow as the primary feedstock. The HEFA pathway also happens to be the same as that by which renewable diesel (RD) is produced. As such, SAF and RD are in direct competition with each other for their feedstocks and the production of the two fuels is often a zero-sum game.

Historically, the policy environment has been more favorable to RD, making it more advantageous to produce.[42] Before the passage of the IRA, SAF cost more to make and RD was being produced at far higher volumes.[43] In the reasoning behind the most recent rulemaking, CARB staff cited the federal Clean Aviation Fuel Tax Credit as part of the impetus for bringing aviation fuel more fully under the LCFS program. With the new federal tax credit and additional state support, the economic tides may be turning.

Based on the most recent spot price data in California's two major markets of San Francisco and Los Angeles, the stacked incentives of federal tax credits and LCFS credit value now make SAF a more valuable commodity to produce (see Exhibit 10).[44] This indicates that further state level engagement, like the direct incentive for SAF recently implemented in Washington, will further tilt the scales in favor of SAF production and may prompt current RD producers to consider SAF production instead.

Exhibit 10 SAF vs RD Incentive Stack

	SAF 20 Carbon Intensity (CI) $/gallon	**RD 20 Carbon Intensity (CI)** $/gallon
Pre-IRA Incentive Stack		
Sample Spot Price	$4.31	$2.62
Cap-and-Trade Cost Added to Petroleum Product		$0.27
LCFS Cost Added to Petroleum Product		$0.11
LCFS Credit Value ($72.00 per metric ton CO_2)	$0.64	$0.65
RINs Value	$2.22	$2.36
Blender's Tax Credit	$1.00	$1.00
Total Value	$8.17	$7.01
Differential	$1.16	
IRA SAF Tax Credit Incentive Stack | 40B for SAF | 40A for RD		
IRA SAF Tax Credit (2023–2024)	$1.53	$1.00
Total Value	$8.70	$7.01
Differential	$1.69	
Clean Fuel Production Credit (CFPC) Incentive Stack | 45Z SAF vs. 45Z other clean fuels		
CFPC Credit (2025–2027)	$1.01	$0.58
Total Value	$8.18	$6.59
Differential	$1.59	

RMI Graphic. Source: RMI Research, OPIS, CARB, EPA

Market challenge

Although the market value and credit stack for SAF have put it on more competitive footing with RD, SAF still faces challenges as a fledgling industry. Airlines typically buy fuel for just months at a time, but SAF producers, and importantly investors, may require more consistent purchases of their product and would benefit from securing long-term contracts from aviation fuel buyers.[45] Renewable diesel, on the other hand, has a far more liquid market into which refiners can sell.

Trade-offs for policymakers to consider

In the inherently competitive SAF and RD markets, policymakers should understand how incentives and program design will continue to influence investor and project decisions.

In 2022, ground transportation in California produced far more greenhouse gas emissions, NOx, and particulate matter than aviation.[46] Additionally, liquid petroleum fuel still makes up most of the fuel consumed in the transportation sector. Advocates for RD argue that the next couple of decades will be an important window to continue displacing conventional diesel fuel and emissions from ground transportation. However, RD has already achieved 50% market penetration, and other technology pathways exist to support ground transportation decarbonization — namely electrification and hydrogen fuel cells.[47] As noted previously, unlike ground transportation, SAF is likely to be the primary driver of emissions reductions in aviation. This means any policy or program that supports RD production over SAF both postpones other deep decarbonization pathways for ground transportation and delays an expanded SAF industry that may be the primary solution for aviation emissions.

Another dynamic for policymakers to consider is providing greater support for eSAF, which avoids the competition for feedstocks with RD and has the potential to provide far greater emissions reductions compared with the current bio-based SAF production we see today. Although it makes sense to support the shift of feedstocks from RD to SAF in the short run, policy that *primarily* benefits current SAF technology pathways could unintentionally undermine investment and innovation in the eSAF industry.

California SAF mandate veto

Given the historic comparative advantage of RD production and California's ambitious climate targets — which include 90% of aviation fuel demand being met by SAF by 2045 — it came as a surprise to many when, in September 2022, California Governor Gavin Newsom vetoed a bill to set SAF production requirements. The bill would have required California to produce 1.5 billion gallons of SAF or blend 20% SAF into the aviation fuel pool by 2030. The reason given for the veto was that the bill would be redundant to the LCFS. However, this decision has faced criticism given that SAF generated just 0.3% of total LCFS credits in 2021.[48]

California and states considering LCFS policies should understand that incentive-only approaches, such as a SAF opt-in, are unlikely to drive the volume of production and blending necessary to meet aviation decarbonization goals on a reasonable timeline. The intrastate mandates for aviation fuel under the proposed LCFS rulemaking are a good start, but they must be the first step in a series of policies that incentivize the production of SAF.

Leading states should explore, implement, and iterate policies that mandate SAF production and complement existing and expanded incentives. New federal incentives will certainly make a difference in SAF production when combined with state LCFS programs like that of California. However, offering carrots without any mandates or sticks has not been sufficient to cause scaling of this industry at the pace necessary.

Potential amendments to California's LCFS program

Amendments to the California LCFS proposed in late 2023 seek to address challenges that have arisen in the program. The changes would take effect in 2024.

Dairy gas CI calculation

Hydrogen produced using methane captured on farms results in a negative-carbon score under the LCFS because of dubious emissions accounting assumptions. This pathway allows for a book-and-claim method of accounting wherein California hydrogen producers contract with dairy farmers anywhere in the country to purchase their environmental attributes for converting biogas from manure into biomethane. The LCFS evaluates this process as carbon negative, based on a faulty assumption that this methane — a potent greenhouse gas — would otherwise have been released into the atmosphere. Capturing it, to be co-fired at a power plant or for some other use, which then breaks down the methane into carbon dioxide, is "carbon negative" due to the differences in global warming potential between the two gases.

The opportunity to sell these environmental attributes claimed via manure digestion methane capture has created a huge incentive within California's LCFS program. In 2019, methane digesters contributed just 5% of the total renewable natural gas in California's LCFS program, but 32% of the total credits.[49]

This incentive could result in producers of hydrogen, a key feedstock for eSAF, purchasing these artificially valuable environmental attributes and appearing to be far lower carbon than what is measured in reality. That discrepancy undermines the integrity of the environmental claim made by the SAF producer. This weakness in proper emissions accounting through the SAF value chain can be detrimental to the long-term trust and validity of the market.

Through this practice, CARB is currently heavily incentivizing gray and blue hydrogen production and increasing emissions via a policy mechanism that is intended to reduce emissions in the transportation sector.[50] Besides the miscounting of emissions, there are also serious environmental justice concerns with dairy gas capture and crediting, including pollution of groundwater, odor, and air quality.

California proposed change: The changes proposed to biomethane crediting are primarily concerned with a slow phaseout of its use as a transportation fuel. The proposed rules would allow any project put in place after December 31, 2029, to earn avoided methane credits through 2040 for biomethane used as a transportation fuel. Those projects could earn avoided methane credits when producing hydrogen through 2045. Any project that exists before 2030 would be exempt from this phaseout.[51]

Biomethane pathways for compressed natural gas vehicles would be phased out by the end of 2040, and pathways for its use to produce renewable hydrogen would be phased out at the end of 2045.

The rules would also implement deliverability requirements for methane that is injected into North American pipelines as an indirect accounting method. For projects breaking ground after December 31, 2029, and pathways that use biomethane to produce compressed natural gas, deliverability would be required starting January 1, 2041. For projects using biomethane as an input to hydrogen production, deliverability would be required starting January 1, 2046.

Lipid-based feedstocks

Currently, biomass-based diesel products are dominating the LCFS credit generation market. In 2021, they made up 45% of all credits generated under the LCFS system.[52] In particular, soybean oil is being used in significant quantities to produce biodiesel in California. Investments in imports and processing capacity expansion suggest that an even greater quantity of these oils will be used for fuel production soon. This is happening despite greater credit incentives for fuels developed from waste residue, tallows, and other feedstocks. This dynamic may be an indication that available supply for these more sustainable feedstocks, and therefore their lower-carbon fuel products, is drying up.

Although this increase in renewable diesel may have some short-term decarbonization benefits, the massive flood of supply entering the market in the coming years may prove to be an overshoot of what is needed and a market anomaly due to policy imbalances.

The increased volume of RD in the California market is creating an oversupply of LCFS credits, driving their value down. This reduction in credit value disincentivizes other producers from entering the market and producing any higher-cost and lower-CI fuels, such as SAF, using waste fats and used cooking oils. The challenge California faces is rebalancing the credit supply under the LCFS so that projects are incentivized to produce high-value, low-carbon fuels.

California proposed change: The proposed amendments seek to implement sustainability criteria for crop-based biofuels, which might affect the volume of credits in the market generated by biofuels. Past rules calculated emissions for crop-based biofuels by assuming that they are being grown on land that was previously agricultural.[53] However, the rising demand for crop-based biofuels has increased the pressure for deforestation and other adverse land use changes.

The proposed rules would require fuel producers to track crop and forestry-based feedstocks to their point of origin and require independent feedstock certification to ensure feedstocks are not contributing to adverse impacts on carbon sinks like forests. They are also proposing to make palm oils ineligible for credit generation, as they have a high deforestation impact. Although this proposed amendment does not directly address the problem of lipids-based feedstocks flooding the market, the additional requirements may reduce crop-based feedstocks entering the LCFS market.

The proposed amendments also include an increased overall CI target of a 30% reduction by 2030 and a 90% reduction by 2045. This increased ambition could help drive more investment toward deep decarbonization solutions. It could also help avoid biofuels overproduction lowering the price of credits, and thus undermining decarbonization of the transportation sector with investments in new, more expensive technologies.

Additionally, the CI target of the proposed program is subject to an auto-acceleration mechanism. This acceleration kicks in if the ratio between the credit bank and the average quarterly deficit exceeds three *and* credit generation is greater than deficit generation based on reporting from the prior year. Once triggered, the mechanism accelerates all subsequent CI benchmarks for the program by one year.

Jet fuel

Currently, jet fuel is treated as an opt-in fuel under California's LCFS, which means a SAF producer can generate credits for producing SAF, but no jet fuel user is obligated to meet any CI reduction targets laid out in the program. By allowing SAF producers to generate credits, but not penalizing traditional jet fuel users for their emissions footprint, this approach is essentially the "all carrot, no stick" option for the aviation industry.

California proposed change: The proposed rules would make intrastate flights an obligated participant in the LCFS market — both as a credit and deficit generator — starting in 2028.

Power-to-liquid fuel and additionality of clean electricity

Power-to-liquid, or eSAF, has emerged as one of the most promising pathways for SAF under LCFS. This is partially because the eSAF pathway does not compete for the same feedstocks as RD. It also avoids much of the environmental harms and emissions caused by ILUC when sourcing crop-based feedstocks. The eSAF pathway is based on a synthetic hydrocarbon that relies on low-carbon production of hydrogen and the use of captured carbon to create a jet fuel substitute that can be "dropped in" to existing jet infrastructure.

The 45V Clean Hydrogen Tax Credit, passed as a part of the IRA, is undergoing Department of Treasury implementation and is the centerpiece of a contentious debate around how to define "clean" hydrogen produced by electrolysis. The debate boils down to whether the clean electricity used for electrolysis needs to be new, local, and matched at an hourly level when producing hydrogen. The Department of Treasury has released a proposed rule that requires all three attributes for clean electricity powering qualified clean hydrogen production. The final rule, expected sometime in mid-2024, will influence how truly low-emissions hydrogen derived power-to-liquid fuels will be.[54] RMI argues that new, local, and hourly matched power, when phased effectively over time, is critical to scaling truly clean hydrogen.[55]

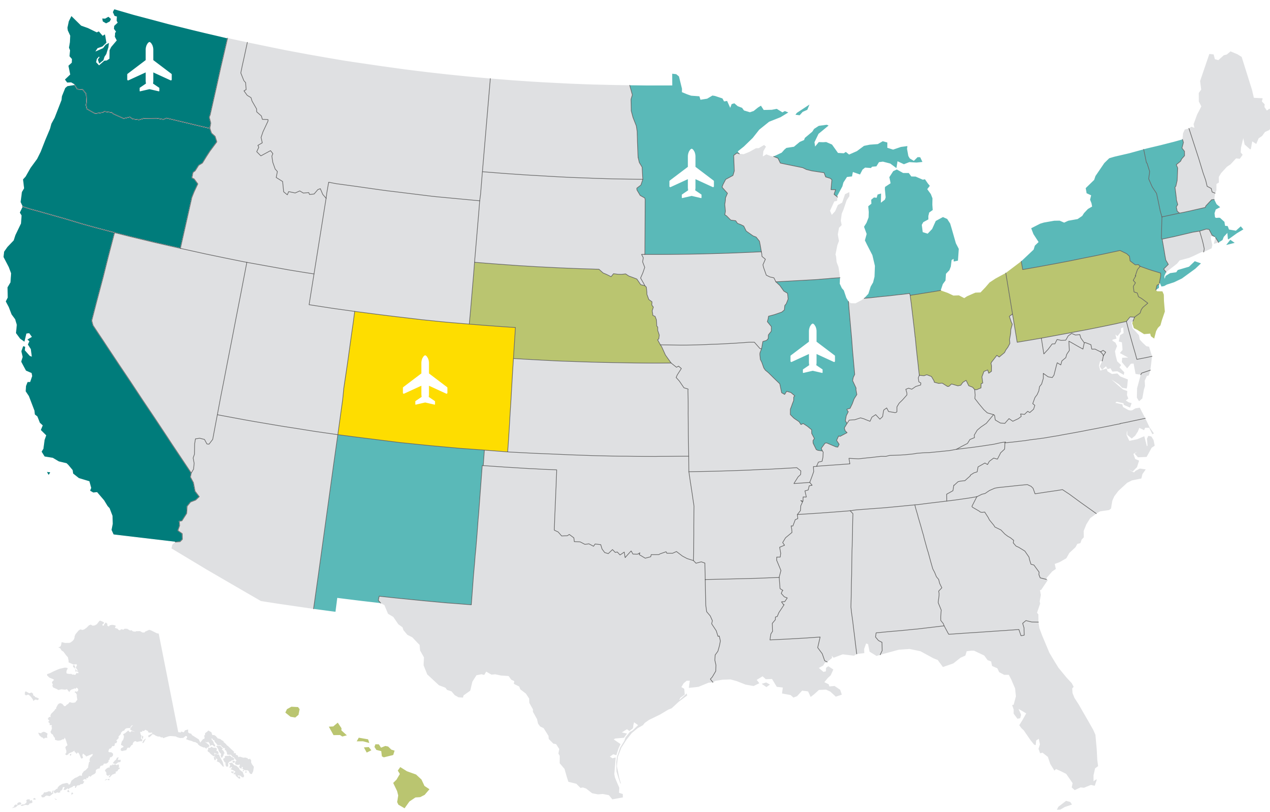
California proposed change: The proposed rulemaking requests the creation of a Tier 1 Carbon Intensity Calculator for hydrogen, which would make it much simpler for hydrogen producers to get their fuels certified under LCFS. Tier 1 CI Calculators use input and emissions factors from tools like Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transport (GREET) model 2022, US EPA's Emissions & Generation Resource Integrated Database 2021, and California Air Resources Board EMFAC emissions model. The way this calculator is eventually finalized will likely determine how California evaluates the CI of hydrogen.

Ongoing state efforts to create an LCFS

Along with California, Washington and Oregon also have clean fuel standards in place, and several other states are in varying stages of passing legislation and implementing their own LCFS (Exhibit 11 and Exhibit 12).

Exhibit 11 **SAF Policy Landscape and Existing SAF Projects**

LCFS or similar policy in force | Pending or failed LCFS or similar policy | No reported activity | Conversations in progress on LCFS or similar policy | Previously considered LCFS



✈ = Direct incentives for SAF in the states of Washington, Colorado, Minnesota, and Illinois.

RMI Graphic. Source: RMI analysis of state policy offices

Exhibit 12 **Summary of State LCFS Features**

State	LCFS Status (and last action)	Bill Name	Final Reduction Goals	Treatment of SAF	Indirect Land Use Change (ILUC) Framework
California	Passed 2009, implemented 2011	Low Carbon Fuel Standard	20% from 2010 level by 2030*	SAF can generate credits but jet fuel is not a mandated fuel.*	The Global Trade Analysis Project (GTAP) model is used to calculate ILUC emissions, with support from the AEZ-EF model.*
Colorado	Colorado previously commissioned an LCFS Feasibility Study	NA	NA	NA	NA
Illinois	Bill introduced, re-referred to assignments	Senate Bill 1556 (2023)	20% reduction by 2038, no baseline proposed	SAF can generate credits but jet fuel is not a mandated fuel.	TBD — no mention in LCA description
Massachusetts	Bill introduced, referred to Ways and Means Committee 6/4/2021	Senate Bill 2130 (2019)	TBD	TBD — no mention.	TBD
Michigan	Bill introduced, referred to Energy and Environment Committee 4/19/2023	Senate Bill 275 (2023)	25% from 2019 levels by 2035	SAF can generate credits but jet fuel is not a mandated fuel.	TBD — does allow for voluntary farm emissions reductions by allowing credit generators to choose between a credit premium or individualized farm-level carbon intensity scoring for approved sustainable agricultural practices
Minnesota	Bill introduced, re-referred back to Environment, Climate, and Legacy Committee 3/13/23	Senate File 2584 (2023)	100% from 2018 levels by 2050	Aviation fuel is a regulated fuel.	Legislation designates Argonne's modeling as the modeling to use for pathways and land use change emissions
New Mexico	Bill introduced, action postponed indefinitely 3/4/23, efforts to get reintroduced	House Bill 426 (2023)	30% from 2018 levels by 2040	TBD	Full fuel life cycle is defined to include indirect emissions including land use changes. No specific framework mentioned.
New York	Bill introduced, sent to rules committee 6/3/2022	Senate Bill S1292 (2023)	20% reduction by 2030, no baseline proposed	SAF can generate credits but jet fuel is not a mandated fuel.	Full fuel lifecycle is defined to include indirect emissions including land use changes. No specific framework mentioned.
Oregon	Passed 2009, implemented 2016	Clean Fuel Program	37% from 1990 levels by 2035	SAF can generate credits but jet fuel is not a mandated fuel.	Argonne's Carbon Calculator for Land Use (CCLUB), which feeds into Argonne's GREET model.
Vermont	Bill introduced, referred to Committee on Natural Resources and Energy 1/19/2023	Senate Bill 24 (2023)	10% from 2018 by 2030	TBD — no mention.	Full fuel life cycle is defined to include indirect emissions including land use changes. No specific framework mentioned.
Washington	Passed 2023, implemented 2024	Clean Fuel Standard	20% from 2017 levels by 2034	SAF can generate credits but jet fuel is not a mandated fuel.	Washington is using ILUC values based on both California's and Oregon's accounting methods.

*These facts reflect the 2018 CA rulemaking as the 2023 proposed rules have not yet been confirmed.
RMI Graphic. Source: RMI analysis

Colorado

In September 2020, Colorado published a Low-Carbon Fuel Standard Feasibility Study.[56] The study discusses SAF and concludes that treating the fuel as voluntary, like California and other programs, would make sense as a precursor to making the fuel an obligated deficit generator.

After completion of the study, Colorado concluded that an LCFS would not be pursued in the near future. The reasons cited include uncertainty as to how an LCFS incentivizing conventional biofuel production for transportation affects emissions and concerns for consumers who cannot afford low-carbon vehicles bearing the costs of the program.[57]

These and other concerns will need to be addressed before Colorado pursues a statewide LCFS program again.

Illinois

Early in 2023, Senate Bill 1556 was introduced to establish an LCFS program in Illinois.[58] Under this legislation, the state's Environmental Protection Agency would be tasked with creating an LCFS that achieves a reduction of transportation fuel CI by 20% by 2038.[59] This bill would fully exempt aviation fuels but allow for SAF to qualify as an opt-in fuel. The bill would also allow for credits generated by SAF to be held by the credit producer and applied to any future obligations or to be sold on the credit market.

Michigan

On April 19, 2023, legislators introduced Senate Bill 275, with the aim of reducing the CI of transportation fuels in Michigan by 25% by 2035.[60] This legislation is included in a broader clean energy package, an approach that can help complement the goals of an LCFS program with other programs and incentives.[61] It includes an accelerator mechanism similar to California's such that if credit availability regularly outpaces deficits, the requirements will become more stringent. Michigan would also allow credit generators to "bank" credits for future use.

Once again, SAF would be allowed as an opt-in fuel, and aviation fuels are exempt from the standards required under this legislation.[62]

Minnesota

Minnesota's latest bill for consideration, the Clean Transportation Standard Act, largely mimics the California LCFS and Oregon Clean Fuels Program with a different choice of baseline year and CI reduction schedule. The measure would require a 25% CI reduction by 2030, 75% reduction by 2040, and 100% reduction by 2050.[63]

Although the bill requiring the establishment of an LCFS in Minnesota has not yet passed, the legislature established the Clean Transportation Standard Work Group to prepare recommendations on final implementation of the expected program.[64] Recommendations from the working group are due February 1, 2024.

There are unique considerations in Minnesota's LCFS process compared with other states including the heavy volume of biofuel production, interests, and blending that already occurs. The state also has a higher share of diesel fuel in its transportation mix than California. As biodiesel and RD continue to benefit as credit generators under state LCFS programs, the question of feedstock availability will quickly come to the fore.

Minnesota's most recently proposed legislation attempts to address some of these issues before they come up by not allowing credits to be generated by biofuels that were grown on cropland with less than five consecutive years of cropping history or from renewable natural gas produced from a new or expanded agricultural livestock production facility. It also would allow for a 10% credit premium for biofuel feedstocks grown on land that uses soil-healthy farming practices, fertilizer best-management practices, or continuous living cover cropping systems.

To support these carve-outs, the legislation instructs the agency to allow biofuel producers to calculate a unique CI score for cropland-produced biofuel feedstocks that considers emissions and sequestration from land management. Farmers could use this unique CI score instead of the statewide average CI value for cropland-derived biofuel feedstocks.

Aviation fuel is again an opt-in fuel for purposes of this program, creating another incentive for producers but without the mandate to reduce the CI of aviation fuel.

New Mexico

After multiple attempts to pass an LCFS, an updated bill was introduced in early 2023, with some changes made from the previous proposal to simplify and align more closely with other state programs.[65] This latest bill would require a 20% CI reduction for transportation fuels by 2030 and 30% reduction by 2040.[66] On September 29, 2023, the Transportation Infrastructure Revenue Subcommittee held a hearing on this bill to explore how an LCFS could affect emissions, economic development, and prices.[67]

Previous LCFS efforts in New Mexico have been derailed by concerns about increased fuel prices.[68] This round of legislation was no different, as fuel prices were one of the main topics of discussion at the hearing. As of this writing, New Mexico's LCFS legislation has been put on a priority bill list and has strong support from both the legislature and the executive branch.

New Mexico's bill would not obligate jet fuel to participate in the program. The final version of the legislation, being considered in early 2024 during the brief New Mexico legislative session, will likely include an opt-in provision for SAF.

New York

Senate Bill S1292 seeks to establish a clean fuel standard and is working its way through the state legislature.[69] New York's Department of Environmental Protection would be tasked with its implementation to achieve a 20% CI reduction in transportation fuel emissions by 2031. As in other states, jet fuel would be exempt from this standard, while still having the ability to opt in and thus be able to generate credits. Once generated, credits may be stored and applied to future obligations. Should this LCFS be signed by the governor, it would be the second-largest system after California's.[70]

Historically, opposition to an LCFS system in New York has in part been due to environmental justice concerns.[71] Environmental justice critiques include the concern that market-based programs prove to be inadequate and leave vulnerable communities to tackle pollution problems associated with transportation in their neighborhoods.

Oregon

In 2020, an executive order in Oregon expanded the existing Clean Fuels Program to establish transportation fuel CI reductions.[72] The program now being implemented has a baseline year of 2015 and targets 10% reduction in CI by 2025, 20% by 2030, and 37% by 2035 — a more aggressive reduction schedule than California's.[73] Oregon classifies jet fuel as an opt-in fuel with no participation mandate for conventional jet fuel.[iii]

Washington

Washington's Clean Fuel Standard is live as of January 1, 2023, and is projected to reduce GHG emissions by 4.3 million metric tons a year by 2038.[74] This policy is expected to work in tandem with the state's Climate Commitment Act to accelerate decarbonization in what is currently the biggest source of emissions in the state.[75] Washington's program requires a 20% reduction by 2034. SAF is an opt-in fuel; there is no mandate to produce and blend SAF. Washington's program uses a combination of the Oregon and California approaches to calculate ILUC.[76]

LCFS Policy Linkage and Alignment

There is interest in California "linking" its LCFS market with those of its neighboring states to create a broader credit market. This idea is based on the linkage of the California Cap and Trade Program with the province of Quebec starting in 2014.[77] Cap and Trade and LCFS are similar programs with similar administrative needs, so the precedent of linking these programs between international partners provides an idea of the burdens, opportunities, and challenges of linking state LCFS programs.

To link or not to link?

Expanding markets promotes liquidity, stabilizes prices, and more effectively distributes carrots and sticks for emissions. Economists often argue in favor of the linkage of carbon markets to stabilize prices, lower the cost of entry to markets, target the greatest culprits more easily, and allow small jurisdictions to have greater emissions impacts.

There may also be benefits to LCFS programs that do not link, or link in some manner without aligning on all rules and policy decisions. State LCFS programs can be considered one form of policy experimentation as conversations around a federal LCFS continue. It could be useful for states to pursue different paths, learn and share lessons, and contribute to a future federal policy based on trial and error and analytical review of different programs.

Steps toward LCFS linkage

Washington's Department of Ecology recently published an economic analysis by Vivid Economics looking at the financial impacts of linking its cap and invest program to California's. Although this isn't the same as linking LCFS programs, it is a step in that direction.[78] The report showed that linking the programs would lower the price of entry into the market.

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iii Oregon also uses a different framework from California for quantifying emissions from ILUC; whereas California uses a combination of the Global Trade Analysis Project model and the AEZ-EF model, Oregon uses Argonne's Carbon Calculator for Land Use, which feeds into Argonne's GREET model.

Washington's H.B. 1092, which established its Clean Fuels Program (CFP), specifically instructs the state Department of Ecology to harmonize the program with other states' LCFS rules where they are not harmonized, likely in anticipation of a regional LCFS credit market. Oregon has a similar system. CFP also has some price control tools to limit credit market volatility and to make sure that credit prices stay aligned with those in other states.

In 2013, California, Washington, Oregon, and British Columbia created the Pacific Coast Collaborative.[79] The collaborative has advocated for linking LCFS markets. In 2021, Hawaii's legislature introduced Senate Bill 987, which would have convened a SAF task force to explore the prospect of Hawaii joining the Pacific Coast Collaborative. The bill stalled in committee.[80]

SAF-Specific Incentives

Beyond a statewide clean fuel standard that incentivizes transportation decarbonization across all modes and sectors, there are policies at the state level designed to specifically encourage SAF production and use.

Colorado

Colorado recently enacted a law that provides a state income tax credit for entities that use clean hydrogen to decarbonize high-value end uses, including aviation.[81] The $1/kg hydrogen ($H_2$) tax credit will be provided for the use of "tier one" hydrogen, or electrolytic hydrogen produced with emissions of less than 0.45 kg CO_2/kg H_2. For hydrogen produced with between 0.45 and 1.5 kg CO_2/kg H_2, the incentive will be $0.33/kg H_2. Further, the emissions accounting rules are such that the hydrogen must be produced from new zero-carbon energy and matched on an hourly basis with hydrogen production — rules like those RMI recommends for the federal clean hydrogen production tax credit (45V).[82]

Colorado also passed a tax credit for the incentivization of SAF production as part of the Tax Policy That Advances Decarbonization (HB23-1272) of 2023.[83] This credit is worth 30% of the cost of construction of a SAF production facility and is available between 2024 and 2033. The total amount the state may pay out for this credit is $1 million in the first year, $2 million for 2025 and 2026, and $3 million for every year after that. The Colorado Energy Office commissioned a feasibility study for the implementation of a low-carbon fuel standard in 2020 and has concluded that it would not pursue one at this time.[84]

Illinois

The Invest in Illinois Act creates a new demand-side state-level credit of $1.50 per gallon of purchased SAF.[85] This credit is effective June 1, 2023–January 1, 2033, and applies to SAF sold to an air carrier or used by an air carrier in the state. This credit structure is unique among state incentives in that it is the purchaser of the SAF — typically an airline — that benefits from this credit by applying it to the sales tax on the purchased SAF.[86] Key policy provisions include a limit on the eligibility of soy-based SAF to 10 million gallons/year, and starting in June 2028, the credit is limited to domestic feedstocks.[87]

Minnesota

In May 2023, the Minnesota legislature passed a transportation package that included a refundable SAF tax credit for blenders and producers. The incentive provides $1.50/kg for SAF blended or produced in the state.[88] It also exempts biofuel construction for SAF from state sales tax.

In August 2023, Minnesota launched a first-of-its-kind SAF hub to accelerate the production and use of SAF.[89] Much of the early coordination, investment, and engagement will center on biofeedstock-based SAF production. This launch dovetails with the announcement in October 2023 that Minnesota, North Dakota, South Dakota, and Wisconsin had secured $925 million for the Heartland Hydrogen Hub through the US DOE Regional Clean Hydrogen Hubs Program.[90] While hydrogen is used as an input in multiple SAF production pathways, it is critical for eSAF, which has the potential for scaling in the Midwest with its abundant renewable energy resources.[91] The coordination of these hubs could be a model for other states and regions to follow.

Washington

In May 2023, Washington enacted a new SAF production tax credit.[92] The credit provides $1/gallon of SAF with a reduction of at least 50% in CO_2-equivalent emissions compared with conventional jet fuel. For every 1% emissions reduction over the 50% threshold, the incentive increases by $0.02 for a maximum benefit of $2/gallon. The SAF tax credit included in the IRA stacked with this type of state incentive (see Exhibit 13) should prove to be a critical factor for investors and producers considering where to pursue future projects and for RD producers considering shifting to SAF production.

Exhibit 13 **SAF vs. RD Incentive Stack Comparison**

Drawing from Exhibit 10, the addition of Washington's state tax incentive demonstrates how much larger the value differential can grow when state policies are stacked onto federal incentives.

	SAF 20 Carbon Intensity (CI) $/gallon	**RD 20 Carbon Intensity (CI)** $/gallon
Clean Fuel Production Credit (CFPC) Incentive Stack 45Z SAF vs. 45Z other clean fuels		
CFPC Credit (2025–2027)	$1.01	$0.58
Total Value	$8.18	$6.59
Differential	$1.59	
CFPC & Sample State Tax Incentive Stack		
Sample State Tax Incentive — Washington (Based on Senate bill 5447)	$1.55	
Total Value	$9.73	$6.59
Differential	$3.14	

RMI Graphic. Source: RMI Research, OPIS, CARB, EPA

Policy Considerations for States

As the federal government rolls out more incentives for SAF, many states are exploring policies that are designed to maximize SAF incentive uptake within their borders and to supercharge the impacts of these federal incentives. States have the opportunity right now to tailor policy in ways that support SAF industry buildout and projects in their state based on natural resources available and workforce readiness. Some states will be better suited to provide biofeedstocks for SAF, some will be better suited to source clean hydrogen and biogenic CO_2 for eSAF, and some will be buyers of SAF to decarbonize major airports and help meet airline, corporate, and state climate goals.

Tax Credits

There are numerous examples of tax credits at the state level that mirror federal tax credits for clean fuel production, including SAF, and clean hydrogen production. When stacked with the federal incentives, these state-level tax credits will help attract financing and innovative projects.

There are also powerful complementary policies at the state level that provide an incentive for the use of clean hydrogen in specific high-level sectors, such as SAF production.

Biofuel Supply and Infrastructure Support

In states with strong biofuel industries, there are loan guarantees, grant programs, and other blending incentives for ground transportation biofuels.[93] These programs should be considered for reform to include SAF produced via biofeedstocks or eSAF to further enable the growth of this industry.

Research and Development

Feedstock availability and technology uncertainty are serious concerns for companies hoping to invest in SAF. Policies that require or support comprehensive SAF feedstock sustainability frameworks, accelerate research and development technologies, and accurately assess life-cycle emissions and environmental impacts of potential SAF technologies would go a long way to responsibly supporting SAF projects and de-risking private investment.

Regulating Jet Fuel in an LCFS

California alone boasts 12 international airports that also facilitate large volumes of intrastate travel. Coordination among states, especially with California looking to do this in its latest LCFS updates, to mandate that conventional jet fuel be an obligated deficit generator under state clean fuel programs will help broaden the policy stick used to drive SAF into the market. As the carrots for SAF production expand and tilt the economic scales, sticks discouraging the use of conventional jet fuel are well timed to further support the industry.[94]

Permitting

Permitting and siting reform will largely happen at the state level in the absence of major federal policy developments. SAF projects themselves have a large footprint and will need support getting built. Additionally, the volume of clean power needed to supply eSAF projects will be significant, which makes siting and permitting of large clean power plants and transmission a critical need for the industry. There are a couple of considerations for accelerating SAF projects through this process: pre-siting and halfway permitted land in special economic or industrial zones or conversion of an existing refinery to a biorefinery that can then produce SAF.

Although change is now afoot, the historic lack of policy signals has discouraged the investment needed to cover the high capital costs of aviation decarbonization. Entities like state government and environmental agencies could prioritize streamlining the permit process for SAF infrastructure as well as facilitate offtake agreements and low-interest loans. Airport leaders, meanwhile, could develop comprehensive strategies to deploy SAF at airports.

Equity and Environmental Justice

SAF is a nascent industry, and education of key stakeholders is critical to scaling the industry and realizing decarbonization goals in aviation. Equity goals and community engagement should be addressed early in project planning stages, and state playbooks and frameworks should be developed to provide a roadmap for projects to do responsible community engagement.

SAF Hubs

Minnesota is demonstrating with its innovative SAF hub how a partnership of businesses, government, and economic development entities can enable the production, transportation, and use of SAF at major airport hubs. This model will work best in states where there are significant volumes of biofeedstocks available, renewable resource adequacy for clean hydrogen production, and an airport with high demand to off-take SAF.

International Perspective

International Civil Aviation Organization Capacity Building

On June 1, 2022, the ICAO launched its Assistance, Capacity-Building, and Training for Sustainable Aviation Fuels program (ACT-SAF), which now has 87 nations and 47 organizations as members.[95] The purpose of this initiative is to provide tailored support for states at different stages in SAF development and use a knowledge-sharing and capacity-building approach to support deployment of global SAF projects. In May 2023, the European Commission (EC) announced a €4 million commitment to 12 developing countries under this program.[96]

Europe

In October 2023, the EC adopted two final pillars of its "Fit for 55" package aimed at meeting the EU's 2030 climate goals.[97] One of those pillars was the ReFuelEU Aviation Regulation, which requires aviation fuel suppliers to blend increasing amounts of SAF going forward. The requirements begin with a 2% blend in 2025, going up to 70% by 2050. Additionally, a specific proportion of this mix must be met with synthetic fuels, such as those generated from power-to-liquid to create a drop-in e-fuel.[98] By 2030, that e-fuel mix must be 1.2%, ramping up to 35% by 2050.

This policy approach mandating SAF blending provides greater certainty for producers that demand will exist far out into the future. This in turn helps with bankability of projects, critical for early movers in the nascent SAF industry. However, this approach is less politically viable in the United States and does not provide a roadmap to follow for federal policy.

British Columbia, Canada

There have been pushes for LCFS policies outside of the United States as well, most notably in Canada. British Columbia's LCFS, first passed in 2008, was the first in North America. In December 2023, the Low Carbon Fuels Act was passed to update the initial regulation.

The new act establishes aviation as a mandatory deficit generator, as opposed to including SAF as an opt-in fuel as in other programs. Under the new regulations, SAF suppliers will be required to incorporate an increasing amount of SAF into the fuel they sell in British Columbia: 1% of all jet fuel in 2028, then 2% in 2029, and 3% in 2030. There is also a scaled carbon-reduction requirement for aviation fuel: 2% in 2026, 4% in 2027, 6% in 2028, and up to 10% reduction by 2030.

Including a volumetric requirement for SAF within the LCFS can help prevent an oversupply of ground transportation credits (potentially cheaper and with lower emissions-reduction benefits compared with SAF) from being used by the aviation industry to comply with the policy. This type of mechanism should be evaluated for every state considering an LCFS policy with the aim of aviation decarbonization and SAF deployment.

Conclusion

Policy support and certainty are necessary to the deployment of SAF as an aviation decarbonization solution. It is critical to understand the available policy levers, and RMI offers recommendations when considering federal and state policy reform and implementation.

Federal incentives

- Extend federal clean fuel credits to provide certainty for SAF producers and investors that policy support will be available along their financial decision-making timelines.
- Require federal agencies involved in the SAF Grand Challenge to establish measurable targets and reporting metrics to ensure that progress is being made on program goals.
- Tech neutrality and emissions-based crediting can help avoid misalignment between policy intent and outcome.
- Combine research and development incentives for advanced biofuels and deep decarbonization pathways with market-based approaches like RFS or LCFS.
- Manage biofeedstock inputs for SAF in the RFS to prevent over-dependence on less sustainable SAF pathways.
- ILUC should be accurately accounted for when evaluating emissions of all low-carbon fuels.
- Encourage federal SAF procurement from production pathways with greatest decarbonization impacts and provide certainty for eSAF pathways by committing to long-term contracts.
- Permitting legislation should include support for greater administrative capacity at the federal level for performing environmental reviews and assessing transmission and pipeline projects for permitting to support critical end uses like SAF production.

State SAF incentives

- Tax credits can come in multiple forms (production, investment, or end use) and can be geared toward different products (hydrogen, SAF). These incentives can stack with federal tax credits and attract investment and projects.
- States should pursue policies that require or support comprehensive SAF feedstock sustainability frameworks, accelerate research and development technologies, and accurately assess life-cycle emissions and environmental impacts of potential SAF technologies.
- Equity goals and community engagement should be addressed early in project planning stages, and state playbooks and frameworks should be developed to provide a roadmap for projects to do responsible community engagement.

State LCFS programs

- Establish lipids management systems in state LCFS programs to avoid overshooting biofeedstock supply and over-incentivizing SAF with significant potential ILUC impact.
- When significant aviation takes place within a state, make intrastate aviation a mandatory deficit generator under the LCFS program.
- Include a volumetric requirement for SAF production when including aviation as a mandatory deficit generator under the LCFS.
- Avoided methane emissions from biomethane captured at landfills and agricultural systems should not qualify as significantly emissions-negative and therefore enable gas-based hydrogen production with high greenhouse gas emissions.
- Continuously consider linkage of LCFS programs, especially when it comes to mandating jet fuel as a deficit generator in interstate flights.

Standards

- Carbon as a feedstock for eSAF should be biogenic (captured at the point source of biomass combustion, such as an ethanol production plant) or collected from direct air capture to qualify as a low-carbon fuel.
- Effective book-and-claim systems must include accurate and transparent traceability, additionality, accounting, and reporting to effectively benefit from investment that can cover SAF green premiums.
- Clean hydrogen used to produce eSAF should, at the very least, follow the rules laid out by the Treasury Department for the federal 45V clean hydrogen production tax credit.

Given the urgency of decarbonizing the aviation sector, creative and certain policy implementation will be critical for industry to innovate, finance to invest, and for airlines to adopt SAF as a decarbonization solution.

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