An Eye to the Sky: Will Sustainable Aviation Fuel Take Off in California?

Andrew Swanson and Aaron Smith

New federal tax credits aim to dramatically increase national production of alternative jet fuels from biofuels. The consumption of sustainable aviation fuels remains low in California despite incentives from the Low Carbon Fuel Standard (LCFS). We compare the incentives for producing biofuels from agricultural feedstocks like soybean oil or ethanol for either on-road or in-air use. We find that the overall balance of incentives is greater for using agricultural feedstocks in non-aviation biofuels than as alternative jet fuels.

California airports supplied over 2 billion gallons of jet fuel in 2022. Consumers, regulators, and investors are pressuring airlines to reduce their carbon emissions. Yet, the aviation industry remains difficult to decarbonize because of the high energy demands of long-haul flights. The electrification of commercial flights remains far beyond the reach of current battery technology, so airlines and regulators are now considering alternative liquid jet fuels known as sustainable aviation fuels, or SAFs for short. SAFs require almost no engine modifications, and they can often be produced in the same facilities as other biofuels.

The Inflation Reduction Act of 2021 (IRA) provides additional tax credits for the production of SAFs in the United States. The goal of these tax credits is to produce over 3 billion gallons of SAF in the United States by 2030, which would be around 15% of total aviation fuel. The total SAF consumption at present only amounts to 1% of aviation fuel use in California and less in the rest of the country. Biomass-based diesel, on the other hand, accounts for two-thirds of all diesel consumption in California. So, will the IRA turn the tide for SAF use in California?

This article discusses the incentives for consuming SAFs in California with an emphasis on the interplay of California's fuel policies, federal fuel policies, and the tax credits from the IRA. SAFs are produced from a variety of different inputs (feedstocks). We emphasize SAFs created from corn ethanol and soybean oil because these are currently the most viable feedstocks for SAF. We compare incentives for consuming biofuels from agricultural feedstocks either on-road or in-air. We find that the overall balance of incentives still tips towards non-aviation biofuels like renewable diesel (RD) and ethanol.

Sustainable Aviation Fuel Incentives

The IRA provides special tax provisions for SAFs in the United States. These tax provisions have two forms: 40B, which ends in December 2024, and 45Z, which runs from 2025 to 2027. The 40B SAF tax credit is a modification of a current tax credit for biofuel diesels called the blender's tax credit. The blender's tax credit provides a $1.00 per gallon tax credit for biomass-based diesels such as soybean oil RD. Fuels must have 50% or more carbon dioxide emissions reduction from petroleum diesel fuel to qualify for the credit. A model of life cycle emissions from the fuel determines the emissions reduction percentage.

The 40B credit adds an additional tax credit of between $0.25 and $0.75 per gallon on top of the blender's tax credit. A qualifying SAF producer receives a minimum of $1.25 per gallon if it has a 50% emissions reduction from petroleum jet fuel. For every 1% reduction beyond 50%, it receives an extra cent per gallon. Therefore, the IRA provides a sizeable incentive to convert biofuels to aviation use instead of on-road usage.

Starting in 2025, the blender's tax credit will be replaced by 45Z in the IRS tax code, which provides a tax credit for all biofuels with a carbon intensity (CI) below 47 grams of carbon dioxide equivalents per megajoule of energy (gCO_2e/MJ). Carbon intensity is a means of measuring a fuel's carbon emissions per megajoule of energy. A fuel receives a tax credit

Table 1. Federal Tax Credits for On-Road and Aviation Biofuels in 2024 and 2025 by Fuel Emissions

Biofuel Emissions	2024 Federal Tax Credits		2025 Federal Tax Credits	
(gCO_2e/MJ)	On-Road Credit ($/Gallon)	Aviation Credit ($/Gallon)	On-Road Credit ($/Gallon)	Aviation Credit ($/Gallon)
45	1.00	1.25	0.04	0.07
30	1.00	1.42	0.36	0.63
15	1.00	1.58	0.68	1.19
0	1.00	1.75	1.00	1.75

Source: Authors' calculations and Congressional Research Service (2023). Available at: https://bit.ly/4c2NOqG.

Note: The 2024 On-Road Credit is the blender's tax credit. The 2024 Aviation Credit is the 40B tax credit. The 2025 On-Road Credit is the 45Z tax credit with a base rate of $1.00 per gallon. The 2025 Aviation Credit is the 45Z tax credit with a base rate of $1.75.

based on the percentage decrease in emission below 47 gCO_2e/MJ. The percentage reduction in emissions is then multiplied by $1.00 per gallon for on-road fuels or $1.75 per gallon for aviation fuels.

Table 1 (on page 5) provides a summary of the different federal tax credits for hypothetical fuels with emissions of 45, 30, 15, and 0 gCO_2e/MJ. In 2024, biofuel diesels earn $1.00 per gallon regardless of the fuel's emissions. The 2024 SAF tax credit starts at $1.25 per gallon for feedstocks with emissions of 45 gCO_2e/MJ and increases steadily to $1.75 per gallon as emissions decrease. In 2025, a fuel with 45 gCO_2e/MJ would provide a small percentage decrease in emissions below 47 gCO_2e/MJ, so both on-road and in-air biofuels would earn less than $0.10 per gallon. Thereby, fuels that barely qualify will lose close to $1.00/gallon in tax credits starting in 2025, and all biofuels with emissions greater than 0 gCO_2e/MJ will see a reduction in tax credits per gallon in 2025 compared to 2024. The one exception is on-road ethanol, which does not qualify for the 2024 on-road tax credit.

Table 2. Incentives to Replace Petroleum With Soybean Oil Renewable Diesel (RD) Versus Soybean Oil Sustainable Aviation Fuel (SAF) in California

	SAF ($/Gallon)	RD ($/Gallon)	Difference ($/Gallon)
Offset Petroleum Fuel Costs			
Fuel Price	2.18	2.33	
D4 RIN Obligation	0.78	0.83	
LCFS Deficits	—	0.09	
Cap and Trade	—	0.39	
Total Petroleum Fuel Costs	**2.96**	**3.64**	-0.68
Plus LCFS Credit Value	0.29	0.30	
Subtotal California Incentives	**3.25**	**3.94**	-0.69
Scenario 1: 2024 Status Quo (CI=40)			
Plus 2024 Federal Tax Credit	1.31	1.00	
Total Incentives	**4.56**	**4.94**	-0.38
Scenario 2: 2024 With CSA (CI=35)			
Plus 2024 Federal Tax Credit	1.35	1.00	
Total Incentives	**4.60**	**4.94**	-0.34
Scenario 3: 2025 Status Quo (CI=40)			
Plus 45Z Tax Credit	0.26	0.15	
Total Incentives	**3.51**	**4.09**	-0.58
Scenario 4: 2025 With CSA (CI=35)			
Plus 45Z Tax Credit	0.45	0.26	
Total Incentives	**3.70**	**4.20**	-0.50

Source: Authors' calculations.
Note: Petroleum fuel costs include wholesale petroleum jet fuel for SAF and wholesale petroleum diesel for RD, D4 RINs for both fuels, and petroleum diesel taxes for RD. Petroleum wholesale prices and taxes are weighted by energy density of relevant biofuel divided by energy density of petroleum fuel as reported by CARB. RINs are weighted by energy density of relevant biofuel divided by energy density of ethanol. LCFS credit values are derived from CARB's formulas. The 2024 Federal Tax Credit is 40B for SAF and the blender's tax credit for RD. CSA soybeans are certified soybeans produced using climate-smart practices that give a 5 carbon intensity (CI) reduction. The 2025 45Z is a federal tax credit according to IRS section 45Z. The difference column is calculated by subtracting the value of RD from the value of SAF.

The Treasury Department awards a reduction in emissions for soybean oil and corn ethanol SAFs that use climate-smart agricultural (CSA) practices. For soybeans, the CSA practices include no-till farming and cover crops, while for corn they also include the addition of inhibitors that prevent the volatilization of nitrogen. Corn ethanol receives a 10 gCO_2e/MJ emissions reduction for these practices, while soybean oil receives 5 gCO_2e/MJ for them. Unlike soybean-oil biofuels, corn ethanol producers will only qualify for SAF tax credits if they certify the use of CSA corn. The certification process could prove to be quite burdensome, as the USDA and private organizations are only now creating CSA pilot programs.

While the IRA is an important recent policy for SAFs, the federal Renewable Fuel Standard (RFS) still plays the largest role in determining national biofuels policy. The RFS mandates the minimum number of gallons of biofuel consumption for ethanol and biofuel diesels, and it divides biofuels into categories based on feedstock, production method, and fuel type. Aviation fuels are exempted from the RFS consumption mandates, but consuming SAFs can offset the consumption mandates on biofuel diesels.

Each fuel category has its own set of compliance credits called Renewable Identification Numbers (RINs). Corn ethanol is in its own category for fuels with at least 20% emissions reduction from gasoline. Soybean oil RD and SAF are in a separate category for fuels with at least 50% emissions reductions from petroleum jet fuel or diesel. Each RIN category has its own separate consumption mandate, but prices for corn ethanol and soybean oil RIN credits follow similar trends.

Incentive Comparisons by Fuel Type

Sustainable aviation fuel consumption in California can take off if the incentives for consumption are strong enough. Sustainable aviation fuel costs roughly 2.5 times as much as petroleum jet fuel to produce, and consumption remains at 1% of the total jet fuel in California. Agricultural feedstocks like soybean oil and corn ethanol have the potential to be converted into SAF, but these feedstocks have competing uses as RD and on-road ethanol—for soybeans and corn respectively. If SAF consumption is going to increase in California, then the incentives for using agricultural feedstocks as aviation fuel must outweigh the opportunity cost of using the same feedstock for on-road use.

Producing aviation fuel instead of on-road fuels likely increases the costs and emissions of biofuels. Dramatically increasing the amount of SAF blended with petroleum jet fuel may also require infrastructure investments from airports. To simplify our analysis, we do not account for these costs. While this simplification favors SAF, it has almost no impact on the primary conclusions of our analysis.

The incentives for using agricultural feedstocks for either aviation or on-road use must weigh the value of the petroleum fuel replaced. We use two components for the value of petroleum fuel replaced: the wholesale cost of petroleum fuel and the additional costs from federal and state carbon regulations. Both are weighted by the ratio of the relevant biofuel's energy content to its petroleum substitute. For example, SAF has roughly 90% of the energy content per gallon as petroleum jet fuel. Replacing a gallon of petroleum fuel with any biofuel needs to account for the fact that biofuel provides less energy per gallon.

In California, petroleum gasoline and diesel are taxed under the LCFS and the Cap-and-Trade programs. Displacing a gallon of diesel or gasoline with biofuels also displaces these taxes. Aviation fuel is not a compliance fuel under these programs, so aviation fuel is not taxed. After accounting for the energy of their respective petroleum fuels, replacing petroleum gasoline or diesel with biofuels eliminates $0.45–$0.50 per gallon in taxes that SAF must overcome to offset the opportunity cost of using on-road biofuels.

Table 2 presents the total incentives for using soybean oil for RD versus SAF in California. The table includes scenarios that differ by the use of CSA soybeans and the version of the federal tax incentive. We use a base carbon intensity (CI) of 40 for RD and 40 for SAF for the IRA tax credits and 50 CI for the California LCFS credits. Differences in the costs of petroleum fuel, the value of RINs, and California carbon taxes on petroleum diesel provide $0.68 of additional value for soybean oil RD over soybean oil SAF. The value of LCFS credits between RD and SAF are almost identical. As a result, RD has a $0.69 per gallon advantage over SAF that federal tax credits must overcome to incentivize switching from RD to SAF production.

Table 3. Incentives to Replace Petroleum Fuel With Corn Ethanol Versus Corn Sustainable Aviation Fuel (SAF) in California

	SAF	On-Road Ethanol	Difference
	($/Gallon)	($/SAF Gallon)	($/Gallon)
Offset Petroleum Fuel Costs			
Fuel Price	2.18	2.89	
D6 RIN Obligation	0.74	0.74	
LCFS Deficits	—	0.10	
Cap and Trade	—	0.34	
Total Petroleum Fuel Costs	**2.92**	**4.07**	-1.15
Plus LCFS Credit Value	0.21	0.20	
Subtotal California Incentives	**3.13**	**4.27**	-1.14
Scenario 1: 2024 Status Quo (CI=50)			
Plus 2024 Federal Tax Credit	—	—	
Total Incentives	**3.13**	**4.27**	-1.14
Scenario 2: 2024 With CSA (CI=40)			
Plus 2024 Federal Tax Credit	1.31	—	
Total Incentives	**4.44**	**4.27**	0.17
Scenario 3: 2025 Status Quo (CI=50)			
Plus 45Z Tax Credit	—	—	
Total Incentives	**3.13**	**4.27**	-1.14
Scenario 4: 2025 With CSA (CI=40)			
Plus 45Z Tax Credit	0.26	0.23	
Total Incentives	**3.39**	**4.50**	-1.11

Source: Authors' calculations.
Note: An SAF Gallon multiplies on-road ethanol values by 1.55 to account for the fact that a gallon of SAF made from ethanol requires 1.55 gallons of corn ethanol to produce it. Petroleum fuel costs include wholesale petroleum jet fuel for SAF and wholesale petroleum gasoline for ethanol, D6 RINs for both fuels, and petroleum gasoline taxes for ethanol. Petroleum wholesale prices and taxes are weighted by energy density of relevant biofuel divided by energy density of petroleum fuel as reported by CARB. RINs are weighted by energy density of relevant biofuel divided by energy density of ethanol. LCFS credit values are derived from CARB's formulas. The 2024 Federal Tax Credit is 40B for SAF. CSA corn is certified corn produced using climate-smart practices that gives a 10 carbon intensity (CI) reduction. The 2025 45Z is federal tax credit according to IRS section 45Z. The difference column is calculated as the value of on-road ethanol minus the value of SAF.

The incentives for using soybean oil SAF are lower than for RD in all of the federal tax scenarios. The 2024 version of the SAF tax credit (40B) reduces RD's advantage to $0.38 and $0.34 for generic and CSA soybeans, respectively. The 2025 version of the federal tax credit (45Z) is less lucrative for all soybean-oil biofuels. As a result, SAF could be even farther behind RD in future years. The use of CSA soybeans helps to close the gap between RD and SAF, but the marginal difference is still not enough to incentivize switching from RD to SAF production.

If SAF were less expensive to produce than RD, then there may still be an incentive for refiners to produce it. However, SAF is more expensive to produce than RD, so it faces even more of an uphill battle.

Table 3 (on page 7) compares using corn-ethanol for SAF consumption versus on-road consumption. It compares different versions of the federal tax incentives and the use of CSA corn. Producers of SAF need 1.55 gallons of ethanol to make a gallon of SAF. We multiply all of the per-gallon values of on-road ethanol by 1.55 to create gallons of ethanol equal to a gallon of SAF. The wholesale value of gasoline displaced by 1.55 gallons of ethanol is $0.71 more than the wholesale value of jet fuel replaced by a gallon of SAF. Carbon taxes add $0.44 to the value of petroleum gasoline displaced by on-road ethanol. Therefore, ethanol SAF has around a $1.15 deficit to overcome before considering any federal tax incentives.

The federal tax incentives provide limited help to corn SAF because the fuel barely qualifies. SAF produced with CSA corn is just below the emissions thresholds for both the 40B and 45Z federal tax credits, so it earns near the minimum for each of the tax credits. The 40B tax credit provided a significant boost in 2024 with a $1.31 credit per gallon of SAF, but the 45Z tax credit hardly moves the needle starting in 2025. The federal tax incentives are proportional to emissions reductions in 2025, so the tax incentives for CSA-corn biofuels are quite small. Any additional processing costs and emissions for corn SAF not accounted for in Table 3 compound the issue, and corn SAF's prospects remain limited in California.

Discussion

Federal tax incentives for SAFs have created a buzz in the biofuel industry and media, but these tax incentives are currently not enough to cover the opportunity costs of diverting agricultural biofuels from on-road to aviation use. The policy incentives for on-road use are larger than for aviation use, and sustainable aviation fuel is more expensive to produce than on-road biofuel. Corn and soybean oil SAFs face significant barriers without either large decreases in their emissions or expanded policy incentives.

California places large carbon taxes on petroleum on-road fuels, and all biofuels have additional value in displacing these taxes. Petroleum jet fuel is exempt from these taxes. This exemption could encourage on-road use instead of aviation use for biofuels. Some groups would like to tax petroleum jet fuel for intra-California flights, which would partially eliminate this exemption.

However, taxing intra-California flights may not encourage more SAF use. Fuel suppliers will comply with carbon regulations in the cheapest way possible. Higher processing costs for SAFs will push fuel suppliers towards on-road biofuels if they are allowed to meet compliance with these fuels. This is why the use of alternative jet fuels remains low compared to biomass-based diesel in states without California's carbon taxes.

If policy incentives were to become large enough to encourage more SAF consumption, it would most likely occur at the expense of on-road biofuels. The RFS and its consumption mandates still appear to be the most important policy in determining national biofuel demand. Additional emissions reductions and volumes from SAFs will likely be small unless the EPA significantly increases mandated volumes. Increasing on-road volumes by an equivalent amount, however, may achieve the same emissions reductions at a cheaper cost because of higher processing costs for SAFs.

Suggested Citation:

Swanson, Andrew and Aaron Smith. 2024. "An Eye to the Sky: Will Sustainable Aviation Fuel Take Off in California?" *ARE Update* 27(5): 5–8. University of California Giannini Foundation of Agricultural Economics.

Authors' Bios

Andrew Swanson received his Ph.D. from the ARE department at UC Davis. He is currently a postdoctoral scholar at UC Davis in partnership with the USDA's Office of the Chief Economist. Aaron Smith is the DeLoach Professor of Agricultural Economics in the ARE department at UC Davis. They can be reached at: acswanson@ucdavis.edu, and adsmith@ucdavis.edu, respectively.

For additional information, the authors recommend:

Swanson, Andrew. 2024. "Is Sustainable Aviation Fuel the Future of Ethanol?" *farmdoc daily* (14):39. Available at: https://bit.ly/3Vt0kKA.

Swanson, Andrew and Aaron Smith. 2024. "Alternative Land-Use Impacts of the Sustainable Aviation Fuel Grand Challenge: Corn Ethanol vs. Soybean Oil Pathways." *American Enterprise Institute*. Available at: https://bit.ly/3yPCGiD.