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ICF Report

Sustainable Aviation Fuel in California's Low Carbon Fuel Standard

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Executive Summary

The pressure for airlines to reduce GHG emissions from passengers, investors, governments, and society has increased in recent years. In December 2023, the California Air Resources Board (CARB) published its Staff Report related to regulatory amendments to California's Low Carbon Fuel Standard (CA LCFS) program, which included a proposal to regulate *intrastate* jet fuel for the first time. During regulatory amendments in 2018, CARB proposed and ultimately approved the opportunity for renewable jet fuel or sustainable aviation fuel (SAF) to generate credits in the LCFS program; however, there was no action at that time to regulate its conventional counterparts.

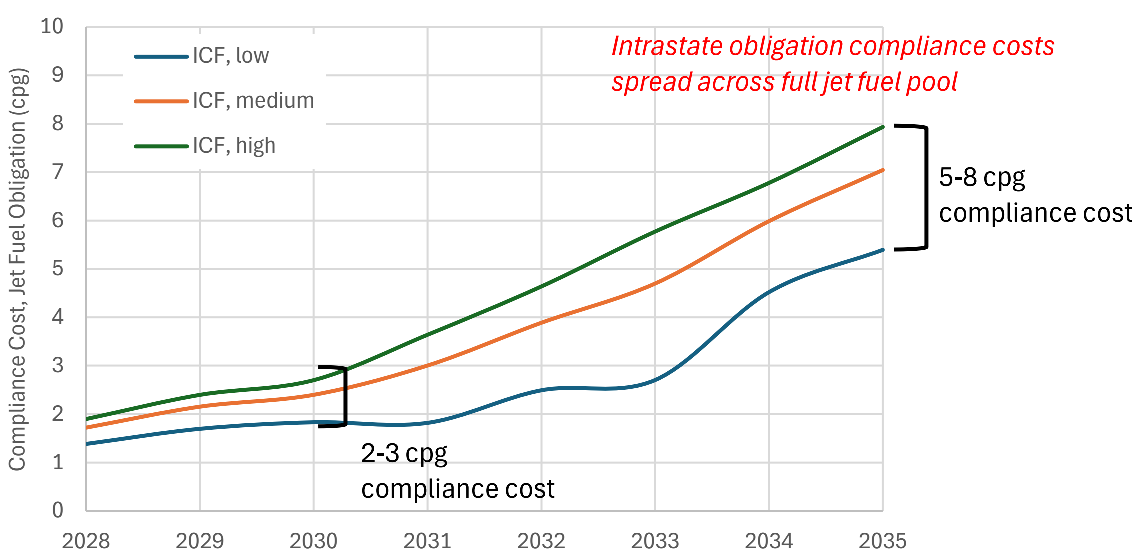
ICF evaluated the potential the compliance costs (in cents per gallon, cpg) associated with regulating intrastate jet fuel and the opportunity for SAF in the California LCFS market in the context of other SAF production incentives and its competitive positioning with respect to another drop-in fuel, renewable diesel.

Jet Fuel Compliance Costs

<u>ICF Conclusion 1:</u> ICF estimates that the potential jet fuel compliance costs associated with an intrastate jet fuel obligation will increase from around 1-2 cpg in 2028 and increase to 5-8 cpg over the period of the analysis to 2035.

ICF's analysis is summarized in the figure below.

ICF Analysis of Jet Fuel Compliance Costs in the CA LCFS w/ Intrastate Jet Fuel Obligation



For the sake of reference, intrastate flights burn jet fuel at a rate of about 1.8 gallons per mile traveled. Considering the flight distance between Sacramento (SMF) and Los Angeles (LAX) is about 375 miles, the implied compliance cost in 2035 is $36 to $54 per flight. ICF assumes that airlines would distribute these costs across both passengers and cargo according to their pricing algorithms, which presumably include customer willingness and ability to pay.

SAF vs RD: Value Stack Differential

<u>ICF Conclusion 2:</u> The value stack differential between SAF and renewable diesel will persist and constrain the opportunity for SAF deployment unless the incentive structure is rebalanced e.g., by including jet fuel in broader decarbonizing policies and via additional state tax incentives.

<u>ICF Conclusion 3:</u> An intrastate jet fuel obligation under the LCFS could help narrow the incentive gap between SAF and renewable diesel and may help shift low carbon fuel producers toward SAF production.

Hydroprocessed esters and fatty acids (HEFA), whereby waste oils and fats, such as used cooking oil and inedible animal fats, are converted into jet fuel, remains the most common pathway for SAF production today, with several emerging competitive SAF production pathways e.g., via alcohol-to-jet (AtJ) processing and Fischer-Tropsch (FT) pathways. SAF production via HEFA and AtJ pathways will compete directly with renewable diesel for investment and for incentive dollars—because these same technologies and facilities produce both renewable diesel and SAF, the incentive gap between the fuels will have a material impact on strategic decision making by producers. Minor production cost differences between SAF production pathways notwithstanding, the incentive value stack is the key factor driving disproportionate supply of renewable diesel and SAF.

The table below shows the incentives available for each fuel when delivered to the California market. ICF made several assumptions to develop these values as outlined in more detail in Section 5 of the report. ICF conducted the analysis for 2025, when the Blender's Tax Credit expires and the market transitions to the Clean Fuel Production Credit (Section 45Z of the Inflation Reduction Act).

Value Stack for SAF vs Renewable diesel in 2025 *without intrastate obligation on jet fuel*

Value Stack Component	Value to SAF $/gal	Value to RD $/gal	Assumptions
Commodity	$2.42	$2.49	June 2024 average
Federal Incentives			
IRA (45Z)	$0.64	$0.37	Assuming 30 g/MJ
RFS	$0.80	$0.85	$0.50 D4 RIN
State			
Low carbon fuel standards	$0.33	$0.34	$50/t, 9% CI stepdown
Carbon compliance costs			
Cap-at-Rack	--	$0.41	$40 CCA
LCFS compliance cost	--	$0.16	$50/t, 9% CI stepdown
TOTAL	$4.19	$4.62	

The key difference between the value stacks is linked to the carbon compliance costs shown in the table above. These are the compliance costs that refiners face because of the carbon constraining programs in California—including the LCFS program and the cap-and-trade program.

1 Introduction

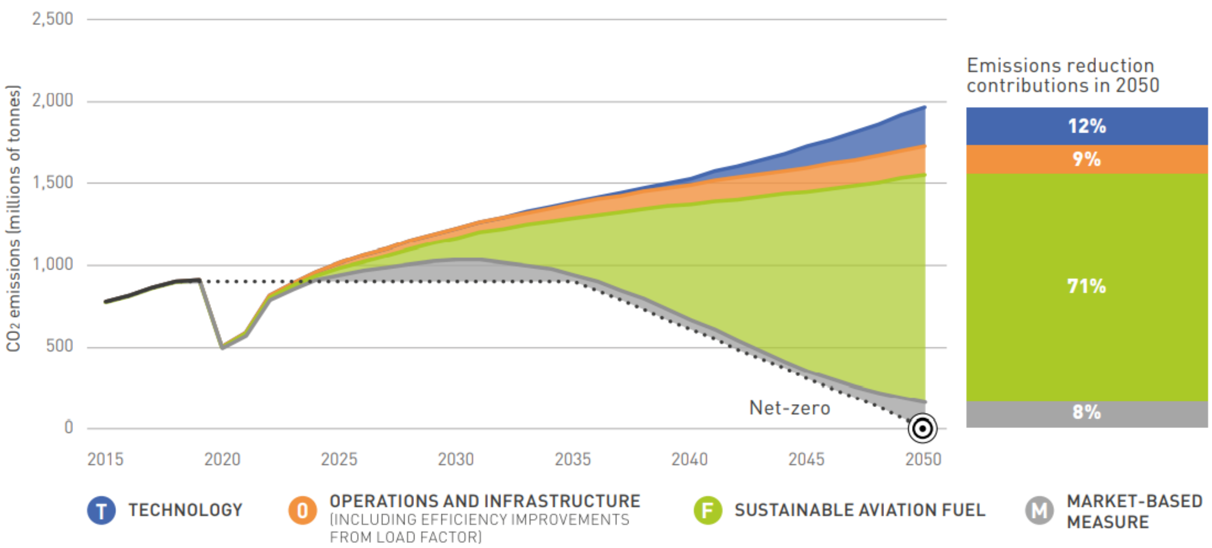
In December 2023, the California Air Resources Board (CARB) published its Staff Report related to regulatory amendments to California's Low Carbon Fuel Standard (CA LCFS) program. The CA LCFS program is one of the main drivers for transportation decarbonization in California, and complements other regulations focused on GHG emission reductions economy-wide (e.g., cap-and-trade) and on the vehicle side of transportation (e.g., Advanced Clean Cars). There was a significant non-road aspect of the Staff Report: CARB has proposed to regulate *intrastate* jet fuel for the first time. During regulatory amendments in 2018, CARB proposed and ultimately approved the opportunity for renewable jet fuel or sustainable aviation fuel (SAF) to generate credits in the LCFS program; however, there was no action at that time to regulate its conventional counterparts.

In the following sections, ICF evaluates the potential compliance costs associated with regulating intrastate jet fuel. ICF also evaluated the opportunity for SAF in the California LCFS market in the context of other SAF production incentives and its competitive positioning with respect to another drop-in fuel, renewable diesel. First, we provide a brief overview of the role of SAF in the context of decarbonizing the aviation sector, and summarize the various incentives available to SAF producers, especially via the Inflation Reduction Act.

2 Decarbonizing the Aviation Sector

The pressure for airlines to reduce GHG emissions from passengers, investors, governments, and society has increased in recent years. It is widely recognized that a basket of four key measures is required for achieving aviation decarbonization by 2050: New technology aircraft, operational improvements, offsets, and sustainable aviation fuels. Considering the energy intensity of medium to long haul flights, and the need for liquid hydrocarbons to meet the energy requirements, SAF is considered as the most important technology to support aviation decarbonization.

Figure 1. Expected Emissions Reductions in Aviation Industry by Reduction Source[1]



The aviation industry has considerable ambitions for SAF as a crucial method to decarbonize the sector, in parallel with aircraft and engine technology development and operational efficiencies. The Air Transport Action Group (ATAG) Waypoint report[2] suggests that up to 390 million tons per year of SAF will be required globally to meet the industry's target of a 50% carbon emissions reduction from 2005 levels by 2050, and over 450 million tons per year to achieve net zero carbon emissions in the same period.

SAF production

Existing SAF production is generally produced via hydroprocessed esters and fatty acids (HEFA), whereby waste oils and fats, such as used cooking oil and inedible animal fats, are converted into jet fuel. This conversion process is cheap, well proven, and is also extensively used to produce renewable diesel. These facilities tend to be large, with typical capacities of 50-500 million gallons per year (MGPY). There are other emerging pathways e.g., via alcohol-to-jet (AtJ) processing and Fischer-Tropsch (FT) pathways. These pathways can convert municipal waste, woody biomass, agricultural residues, industry waste gases, etc. into jet fuel and renewable diesel. Several facilities are under construction. These facilities are more complex and costly, but their feedstock can be cheaper. Compared to existing HEFA facilities, they are less sensitive to feedstock prices, have fewer constraints on feedstock availability, but use less proven technology. The initial facilities are expensive, but the cost is expected to rapidly decrease as the technology is improved.

1 ATAG Waypoint 2050 Report, scenario 2
2 *Ibid.*

3 Incentivizing SAF

There is an interesting dynamic emerging with respect to incentivizing SAF, in large part because it is more expensive than its conventional counterpart and because it is significantly disincentivized as compared to diesel substitutes like renewable diesel, in part as a result of the existing exemption for jet fuel under existing regulations like Cap-and-Trade and the LCFS program. To overcome these obstacles and expand SAF consumption, additional policy support will be necessary e.g., via additional incentives or regulatory intervention that helps to level the obligation across refined products, including gasoline, diesel, and jet fuel.

The current incentive-only domestic regulatory structure includes several components (see Table 1), including via the Inflation Reduction Act (IRA) from 2022, the federal Renewable Fuel Standard (RFS), state-level programs like the California LCFS, Oregon Clean Fuels Program (OR CFP), and Washington's Clean Fuel Standard (WA CFS), and state-level tax incentives.

Table 1. SAF Incentives and Renewable Diesel

Incentive	Description	
Federal	Sustainable Aviation Fuel (SAF)	Renewable Diesel (RD)
Biodiesel Mixture Excise Credit Blenders Tax Credit (BTC)	• SAF is not eligible for the Biodiesel BTC.	• RD is eligible for a tax incentive up to \$1.00 per gallon blended with petroleum diesel.
Inflation Reduction Act 2022	• For 2023-2024, the SAF Blender's Tax Credit (Section 40b) offers \$1.25 per gallon for producers achieving a GHG emission reduction of at least 50% compared to petroleum-based jet fuel. Producers will receive an additional \$0.01 per percentage reduction over the 50% requirement, with a maximum benefit of \$1.75 per gallon. • For 2025-2027, the Clean Fuels Production Credit (CFPC, Section 45z) will go into effect and provides a per gallon incentive for SAF with lifecycle GHG emissions reductions less than 50 $kgCO_{2e}$/mmBtu. If wage and apprenticeship requirements are met, the base value is \$1.75 per gallon of SAF multiplied by the percent reduction below the 50 $kgCO_{2e}$/mmBtu threshold.	• For 2025-2027, the Clean Fuels Production Credit (CFPC, Section 45z) will go into effect and provides a per gallon incentive for RD with lifecycle GHG emissions reductions less than 50 $kgCO_{2e}$/mmBtu. If wage and apprenticeship requirements are met, the base value is \$1.00 per gallon multiplied by the percent reduction below the 50 $kgCO_{2e}$/mmBtu threshold.

Incentive	Description	
Renewable Fuel Standard • The federal RFS requires volumetric blending of renewable fuels and SAF is eligible to contribute towards compliance by generating Renewable Identification Numbers (RINs) i.e., the currency through which compliance is achieved. • RINs are reported as ethanol gallon equivalents	• SAF is eligible to generate D3, D4, D5, D6, and D7 RINs depending on the feedstock, conversion technology, and product • SAF has a 1.6 multiplier for RINs after adjusting for the energy density of the fuel compared to ethanol.	• RD is eligible to generate D3, D4, D5, D6, and D7 RINs depending on the feedstock, conversion technology, and product • RD has a 1.7 multiplier for RINs after adjusting for the energy density of the fuel compared to ethanol.
State		
Low carbon fuel standards • Low carbon fuel standards in California, Oregon, and Washington establish carbon intensity benchmarks against which the transportation fuel market must achieve aggregate GHG emissions reductions each year.	• SAF is an opt-in fuel for these programs and generates credits depending on the CI of the fuel and the benchmark in any given year. • However, petroleum jet fuel is not regulated in any of these programs today. • California has proposed to regulate intrastate jet fuel.	• RD is an opt-in fuel for these programs and generates credits depending on the CI of the fuel and the benchmark in any given year. • Petroleum diesel is regulated in these programs uniformly; because of this, the value generated by RD in the program includes what are often referred to as "avoided deficits" i.e., by displacing petroleum diesel with RD, credits are generated, and deficits are also avoided by displacing petroleum diesel.

4 Compliance Costs

With a focus on accelerating decarbonization of aviation fuels in line with deep greenhouse gas (GHG) emission reductions called for in AB 1279 and the 2022 Scoping Plan Update, and to incentivize SAF production further, CARB staff proposed to eliminate the exemption to *intrastate* jet fuel starting in 2028. The exemption would be lifted for "flights that take off and land withing the State of California." As one might expect with any regulatory amendment, questions have been raised regarding the associated compliance costs.

> With this context, we express our serious concern with a new proposal by the California Air Resources Board (CARB) to regulate jet fuel as an obligated fuel under the LCFS Program. CARB's proposed changes to the LCFS program include a proposal to eliminate the existing exemption for conventional jet fuel use for flights within the state of California. This proposed change is unlikely to

result in increased SAF production, availability, or use in California, but would lead to higher jet fuel prices.[3]

ICF notes two things with respect to this commentary: 1) higher jet fuel prices will inherently lead to improved SAF production economics by narrowing the subsidy needed and 2) these comments are silent on the magnitude of the impact on jet fuel prices. With regard to the former, ICF takes up the issue of the incentive gap for SAF relative to renewable diesel in the next section. With regard to the latter, ICF has quantified the likely impact on jet fuel prices by making a simple assumption: Regulated parties (i.e., refiners) will pass through the compliance costs entirely to end users (e.g., airlines), and that those end users would ultimately pass along any compliance costs to consumers (i.e., airline passengers). In other words, ICF is simplifying the consideration of consumer costs by assuming that they are equal to compliance costs, though there is nothing in the LCFS program or other regulation that requires compliance costs to be passed through as consumer costs.

ICF also assumes that the compliance cost associated with regulated intrastate jet fuel would get spread over the entirety of the jet fuel pool in California, rather than exclusively on intrastate jet fuel. To our understanding, there is no clear method by which jet fuel suppliers or jet fuel users would be able to distinguish at the point of sale between regulated and exempted gallons—therefore it is likely that the transaction will likely include a line item for LCFS compliance cost as is customary for gasoline and diesel transactions.

ICF's assumption is backed in large part by the existing treatment of compliance costs and consumer costs in the diesel market in California. Although the "diesel pool" includes conventional ultra-low sulfur diesel (ULSD), renewable diesel, and biodiesel, the LCFS compliance cost is spread over each blended gallon sold statewide as a consumer cost; there is not a separate cost allocated to specific gallons based on their regulatory status. A similar convention has evolved in the gasoline pool, in which ethanol (a low carbon fuel) is blended with gasoline.[4] The compliance costs on the gasoline portion of the blend are spread over the entire gallon of fuel and passed on as consumer costs. These examples demonstrate the impracticality of distinguishing between aspects of the fuel pool with respect to characterizing compliance costs (and how they become consumer costs). ICF expects a similar convention will emerge for intrastate jet fuel when it is regulated in 2028.

ICF developed estimated compliance costs for obligated jet fuel in several different cases. More specifically:

- ICF assumed that the jet fuel obligation begins in 2028, as proposed.
- ICF used our own internal LCFS credit price forecasting to characterize the potential compliance cost impacts on jet fuel associated with CARB's proposed elimination of the exemption for intrastate jet fuel. ICF used three different credit price cases in the analysis, with

[3] See comments submitted by Airlines for America, Alaska Airlines, American Airlines, the San Francisco Chamber of Commerce, and Southwest Airlines.
[4] More specifically, as California Reformulated Blendstock for Oxygenate Blending (CARBOB).

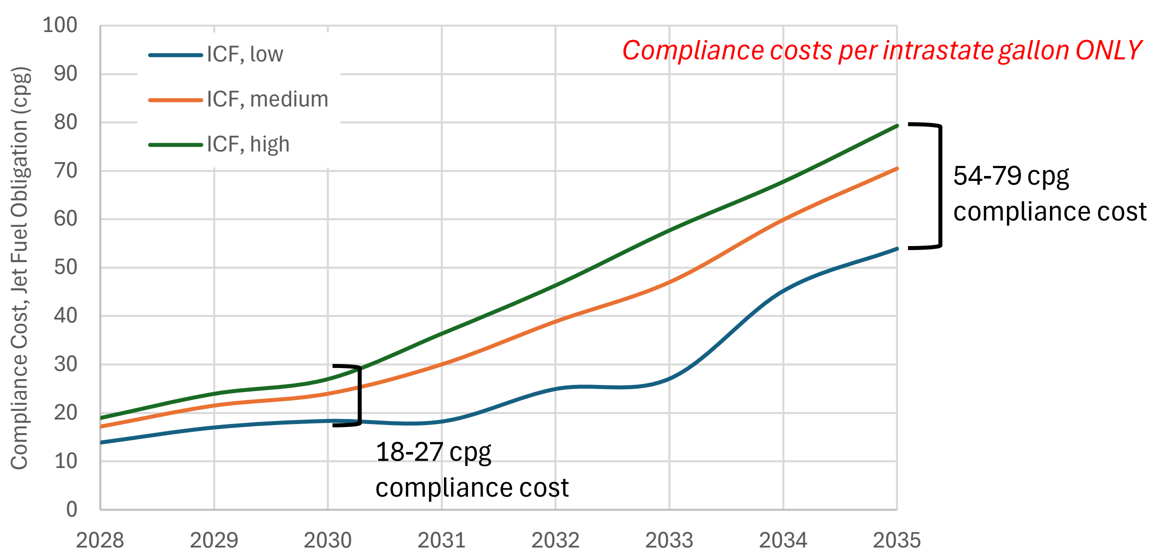
changes to assumptions regarding a) the carbon intensity (CI) step down in 2025 and b) the Automatic Acceleration Mechanism (AAM), with a focus on when it can be triggered, and how it is triggered (see table below).

Credit price case	Description
Low	• Aligned with Staff Report from December 2023. • 5% CI step down in 2030 • AAM available for trigger earliest Jan 1, 2028
Medium	• Modified case with 9% CI step down in 2030 • AAM available for trigger earliest Jan 1, 2028
High	• Modified case using ICF analysis with a 10.5% CI step down in 2025 • More sensitive AAM and trigger sooner (2026, if needed)

- As noted above, the compliance cost is most likely to be spread across the entire jet fuel pool as the obligation on intrastate jet fuel comes into effect. However, for the sake of comparison, ICF has included an analysis of the compliance costs if they were concentrated on just intrastate jet fuel, which is estimated to be about 10% of the jet fuel pool.
- Accordingly, for the sake of simplicity, ICF has assumed that intrastate jet fuel that will be regulated is a constant 10% of the total jet fuel in California.

Figure 2 below shows ICF estimates for the compliance costs based on *per gallon of intrastate jet fuel* and shown in units of cents per gallon (cpg) on the y-axis. As a reminder, this implies the unlikely situation in which there will be a convoluted accounting scheme whereby sellers are able to apply the compliance costs exclusively to the obligated intrastate jet fuel gallons. ICF notes that the prices are shown in nominal terms.

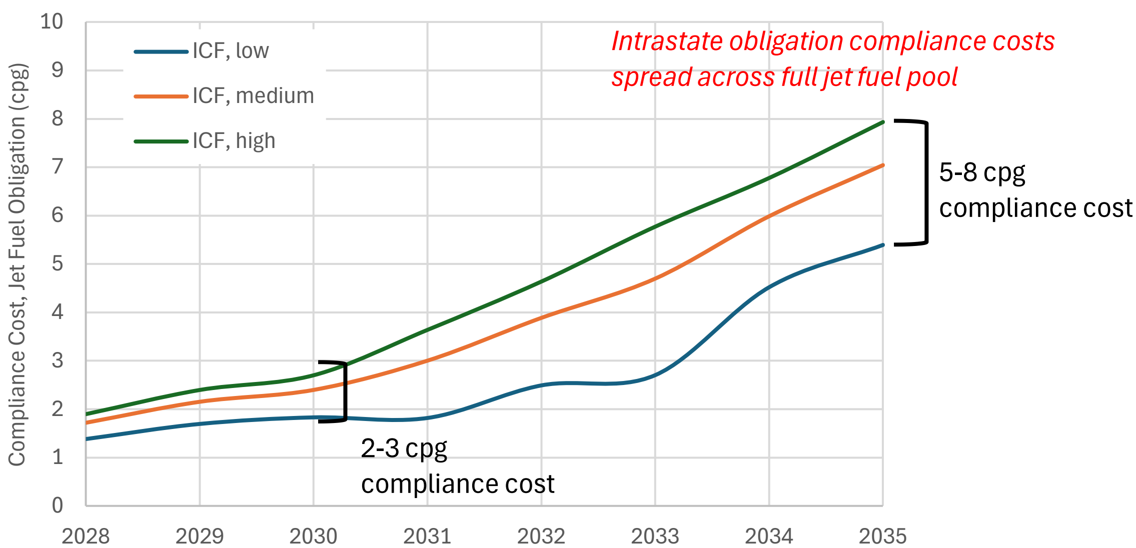
Figure 2. ICF Analysis of Jet Fuel Compliance Costs for Intrastate Gallons ONLY in the CA LCFS



This unlikely scenario yields compliance costs of 18-27 cpg in 2030 for intrastate gallons and 54-79 cpg for intrastate gallons using ICF's LCFS credit pricing forecasts. Furthermore, in this unlikely scenario, there would be no compliance cost on jet fuel for non-intrastate gallons. ICF notes that the compliance costs shown in Figure 2 are consistent with the expected compliance costs for diesel fuel moving forward.

Figure 3 below shows ICF estimates for the compliance costs associated with regulating intrastate jet fuel from 2028 to 2035 (noting that all prices are shown in nominal terms).

Figure 3. ICF Analysis of Jet Fuel Compliance Costs in the CA LCFS w/ Intrastate Jet Fuel Obligation



ICF estimates that the potential jet fuel compliance costs will increase from around 1-2 cpg in 2028 and increase to 5-8 cpg over the period of the analysis to 2035. For the sake of reference, intrastate flights burn jet fuel at a rate of about 1.8 gallons per mile traveled. Considering the flight distance between Sacramento (SMF) and Los Angeles (LAX) is about 375 miles, the implied compliance cost in 2035 is $36 to $54 per flight. ICF assumes that airlines would distribute these costs across both passengers and cargo according to their pricing algorithms, which presumably include customer willingness and ability to pay.

5 Value Stack: Renewable Diesel vs SAF

As noted previously, HEFA remains the most common pathway for SAF production today, with several emerging competitive SAF production pathways e.g., via AtJ or FT processing in the market. SAF production via HEFA pathways will compete directly with renewable diesel for investment and for incentive dollars—because these same technologies and facilities produce both renewable diesel and SAF, the incentive gap between the fuels will have a material impact on strategic decision making by producers. There are differing views on the production costs associated with renewable diesel and SAF production; and any production cost difference across technologies is minor. Minor production cost differences notwithstanding, the incentive value stack is the key factor driving disproportionate supply of renewable diesel and SAF We focus here on the California LCFS market.

The table below shows the incentives available to each fuel, drawing from the information presented in Table 1 above. ICF made several assumptions to develop these values. ICF conducted the analysis for 2025, when the Blender's Tax Credit expires and the market transitions to the CFPC for SAF and renewable diesel. ICF assumed a CI value of 30 g/MJ for both the CFPC calculation and the LCFS value calculation—we note, however, that it is highly unlikely that a fuel will have the same CI value across these two programs given the differences between the 40B SAF GREET model and the CA-GREET model. The table below includes other assumptions made in ICF's analysis.

Table 2. Value Stack for SAF vs Renewable diesel in 2025 without intrastate obligation on jet fuel

Value Stack Component	Value to SAF $/gal	Value to RD $/gal	Assumptions
Commodity	$2.42	$2.49	June 2024 average[5]
Federal Incentives			
IRA (45Z)	$0.64	$0.37	Assuming 30 g/MJ
RFS	$0.80	$0.85	$0.50 D4 RIN
State			
Low carbon fuel standards	$0.33	$0.34	$50/t, 9% CI stepdown
Carbon compliance costs			
Cap-at-Rack	--	$0.41	$40 CCA
LCFS compliance cost	--	$0.16	$50/t, 9% CI stepdown
TOTAL	$4.19	$4.62	

The key difference between the value stacks is linked to the carbon compliance costs shown in the table above. These are the compliance costs that refiners face because of the carbon constraining programs in California—including the LCFS program and the cap-and-trade program. Renewable diesel producers, providing a drop-in substitute for diesel, have been able to capture these "avoided compliance costs" as part of their revenue streams.[6] Other blended biofuels, like biodiesel and ethanol, lack the same substitutability as renewable diesel and with physical blending limits have been unable to command this premium in the market. It is unclear the extent to which SAF will be able to capture the avoided carbon costs in the LCFS program—but because jet fuel is not regulated via California's cap-and-trade, it most certainly will not capture any cap at the rack benefit shown for renewable diesel. An intrastate jet fuel obligation under the LCFS could

[5] The commodity price listed for SAF is ICF's analysis of daily Argus LA Spot for jet fuel. The commodity price listed for renewable diesel is the Ultra-Low Sulfur No. 2 Diesel Fuel price reported by the EIA for Los Angeles posted here.

[6] There is emerging evidence that renewable diesel providers are and will continue to have to discount their pricing via this carbon compliance costs to maintain competitiveness

help narrow the incentive gap between SAF and RD; however, it cannot do so fully. Regardless, any narrowing of the incentive gap may help shift low carbon fuel producers toward SAF production.

Spot prices and environmental commodity pricing will vary in California, the CI values will vary by feedstock, and the IRA incentives for SAF will be finalized soon. However, this view of the SAF-RD differential highlights a nearly 43 cent per gallon premium for renewable diesel, which will increase over time as compliance costs on diesel increase but remain at zero for jet fuel. ***This value stack differential will likely continue to constrain the opportunity for SAF deployment unless the incentive structure is rebalanced e.g., by including jet fuel in broader decarbonizing policies and via additional state tax incentives.***

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