TECHNOLOGY WORKING GROUP

SUSTAINABLE AVIATION FUEL: POLICY RECOMMENDATIONS TO ENABLE A LOW-CARBON FUEL MIX

C2ES CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Center for Climate and Energy Solutions

December 2024

Meeting our long-term climate goals will require the large-scale deployment of a multitude of new, innovative technologies and low- and zero-carbon fuels across every sector of the economy. First-of-a-kind technologies will need to rapidly reach commercial scale without sacrificing safety, social equity, or sustainability. This can only be achieved through systemwide collaboration between corporate incumbents, financiers, innovators, communities, and policymakers. To help meet this challenge, the Center for Climate and Energy Solutions (C2ES) has created four distinct technology working groups focused on the technologies of sustainable aviation fuel, long duration energy storage, clean hydrogen, and engineered carbon removal. This brief presents findings and recommendations from the sustainable aviation fuel working group.

OVERVIEW

From pioneering technical advancements to commercial aviation dominance, the United States has been a leader in the aviation sector since the industry's inception. In today's era of global economic development, the aviation industry is projecting major growth and, with it, major challenges in the context of rising greenhouse gas emissions. Forward-thinkers in every sector of the economy are pursuing technologies and practices to slash emissions. While aviation is no exception, decarbonizing the sector is particularly challenging due to weight limitations and the energy density of fuels, which create a narrow window of acceptable solutions to cut aviation emissions. New airframes, engines, and operational practices can reduce fuel burn beyond historic rates, but today's two percent average annual fuel efficiency improvements are easily overtaken by annual passenger growth.[1] Some proposed solutions to reduce aviation emissions include shifts to rail and more efficient transportation options that can substitute for some air traffic where practical (i.e., over shorter distances). However, among the best options for reducing emissions in the near- to mid-term is the deployment and uptake of non-petroleum jet fuel, commonly referred to as Sustainable Aviation Fuel (SAF).[2]

The definition of SAF varies significantly depending on context, with most statutory definitions including criteria on carbon intensity, environmental safeguards, or feedstocks. In general, SAF is a jet fuel which is produced from non-petroleum feedstocks as a biofuel or hydrogen-based synthetic fuel. The value proposition of

SAF is three-fold: its total lifecycle emissions are lower than fossil jet fuel, it can be produced domestically, and it is certified for use in today's aircraft. While all three of these components demonstrate its potential to reduce jet fuel emissions in the United States and abroad, its compatibility with today's aircraft is key to its high near-term adoption potential. The average 25-year lifespan for passenger aircraft, of which there are over 7,000 amongst U.S. carriers, necessitates drop-in liquid fuels regardless of the pace of advancement for electric and hydrogen-powered aircraft.[3]

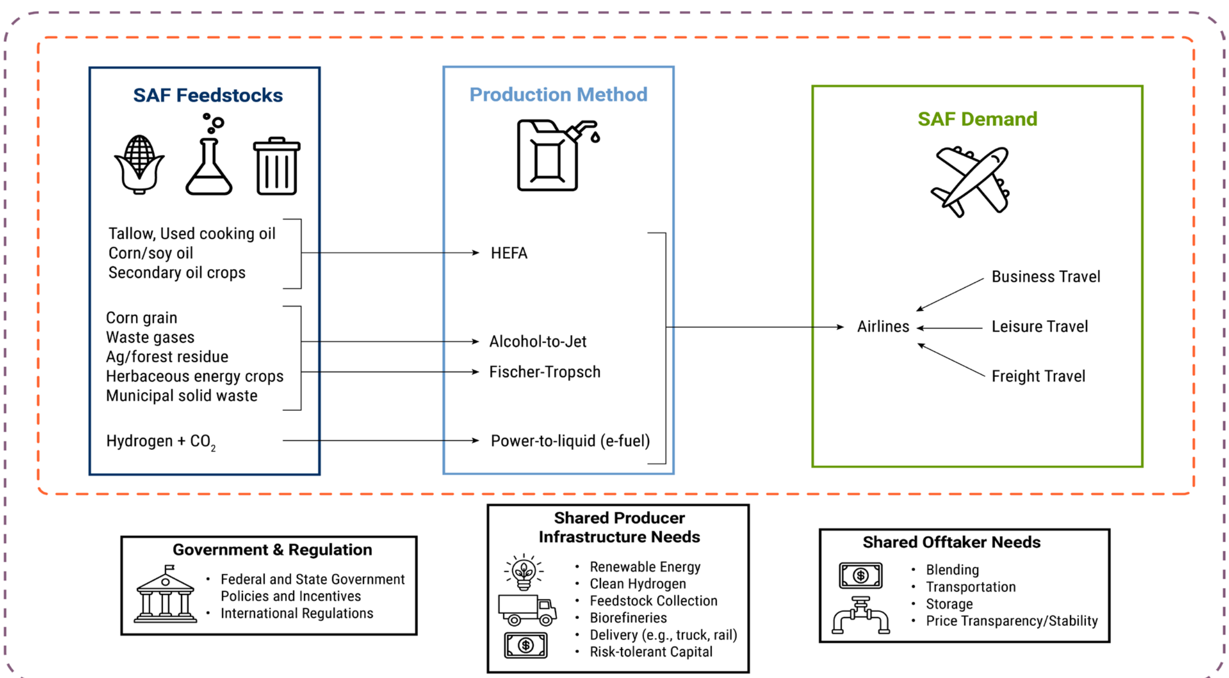
The nascency of the SAF market is both a challenge and an opportunity. Jet fuel consumption in the United States reached 25.3 billion gallons in 2023, and only 23 million gallons of that fuel was SAF (a penetration rate of 0.09 percent).[4] Decarbonizing the aviation industry will require accelerating the adoption of SAF. To help meet this challenge, the Center for Climate and Energy Solutions established a technology working group that convenes stakeholders from across the SAF ecosystem (see Figure 1) to examine the key technical, market, and policy solutions needed to remove key barriers toward the sustainable commercialization of this important technology. This brief offers a shortlist of four policy recommendations following the working group's inaugural year.

INTRODUCTION

THE GROWING IMPORTANCE OF DOMESTIC SUSTAINABLE AVIATION FUEL PRODUCTION

SAF is projected to account for only 0.53 percent of global aviation fuel in 2024; however, global economies are establishing targets of up to 10 percent SAF blending by 2030.[5] For instance, the European Union is requiring that fuel dispensed at EU airports be composed of SAF, starting with two percent in 2025 to six percent in 2030.[6] The United Kingdom is implementing a similar policy, increasing from two percent in 2025 to 10 percent in 2030.[7] In the Asia-Pacific region, Japan is targeting a 10 percent SAF blend by 2030, China is building new SAF production and research capacity, Singapore is implementing SAF targets for departing flights at one percent in 2026 and three to five percent by 2030, and India is eying targets of a one percent SAF blend on domestic

FIGURE 1: The SAF Ecosystem



flights by 2025 and one percent on international flights by 2027.[8] These targets represent significant opportunities for U.S. companies to capture this market growth.

The United States has also set goals to produce 3 billion gallons of SAF by 2030 and 35 billion gallons of SAF by 2050 under its multi-agency SAF Grand Challenge Initiative.[9] The effort seeks to expand supply, reduce costs, and improve the sustainability of SAF production, which may draw upon a diverse set of feedstocks and production pathways that range in emissions reduction potential and technical maturity (see Box 1). Most of global and U.S. SAF production in the 2020s will convert feedstocks like vegetable oils, animal fats, and used cooking oils into fuel. By the end of this decade and into the 2030s, alcohol-based fuels, such as those from corn grain and sugarcane, are expected to account for an increasingly large portion of SAF produced in the United States.[10] As the number of production methods meeting international specifications continues to grow, leveraging more advanced feedstocks such as captured carbon dioxide, hydrogen, and cellulosic materials (i.e., non-food crops and crop residues) will be important in reducing the overall environmental impact of SAF as an emerging fuel product.[11]

CURRENT U.S. POLICY FRAMEWORK FOR SAF

The current policy framework supporting SAF production in the United States includes tax credits and market-based incentives (e.g., state-level low-carbon fuel standards and the federal Renewable Fuel Standard), government grants, and access to loan guarantees. The 40B Sustainable Aviation Fuel Credit (2023–24) provides incentives based on the fuel's emissions performance ranging from $1.25 to $1.75 per gallon, provided it achieves a reduction of at least 50 percent compared to petroleum fuel. The 45Z Clean Fuels Production Tax Credit (2025–27) will continue the per-gallon tax credit but without a floor price.

Additionally, Congress made funds available as discretionary grants to be administered under the Federal Aviation Administration (FAA) for the Fueling Aviation's Sustainable Transition (FAST) program, which allocated $244.5 million toward infrastructure projects related to SAF production, transportation, blending and storage.[12] Grants available under the Department of Energy's Bioenergy Technologies Office (BETO) are also available to support the development and demonstration of biofuels including SAF. Since 2021, BETO has awarded $151 million in funding for 28 projects, leveraging $156 million in private sector funding.[13] The Department of Energy's

BOX 1: Sustainable Aviation Fuel Production Technologies and Feedstocks

SAF can be produced using a wide range of production methods. Each method is accredited under ASTM International, an international standards organization which ensures the quality and suitability of fuels for use in aircraft. Each production pathway involves a unique chemical process; however, in general, they convert non-petroleum feedstocks into a liquid fuel that can be blended with conventional jet fuel and used in today's aircraft. The number of approved pathways continues to grow (11 as of July 2023). While by no means an exhaustive list of feedstocks and conversion methods, three production pathways in particular are expected to play an outsized role leading up to 2030:

EXAMPLE FEEDSTOCKS	PRODUCTION TECHNOLOGY	COMMERCIAL READINESS
Used cooking oil, tallow, corn oil, soy oil	Hydroprocessed esters and fatty acids (HEFA), Co-processing	In production.
Ethanol derived from corn grain or sugarcane	Alcohol to jet (AtJ)	The first commercial scale AtJ facility was commissioned in 2024.*
Captured carbon dioxide (e.g., biogenic CO_2 captured from ethanol production) and clean hydrogen produced from water electrolysis	Power-to-liquid (e-SAF) using Fischer-Tropsch (FT) conversion	The first fully operating commercial e-fuel facility was commissioned in 2024.†

** U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "World's First Ethanol Jet Fuel Plant Paves the Way for Commercial Production of Sustainable Aviation Fuels," February 29, 2024, https://www.energy.gov/eere/bioenergy/articles/worlds-first-ethanol-jet-fuel-plant-paves-way-commercial-production.*

† Infinium, "Infinium's Project Pathfinder Is World's First Fully Operational eFuels Facility," Infinium News, March 21 2024, https://www.infiniumco.com/news/infiniums-project-pathfinder-is-worlds-first-fully-operational-efuels-facility.

Loan Programs Office may also award loan guarantees for SAF projects, including up to $1.9 billion in conditional commitments announced across two projects in October 2024.[14]

The implementation of these tax, grant, and loan resources and a targeted multi-agency focus under the SAF Grand Challenge has created a more favorable environment for the domestic production of SAF. However, despite production volumes increasing from about 5 million gallons in 2021 to nearly 15 million gallons in 2023, imported SAF volumes through June 2024 significantly outpace estimated domestic volumes.[15] To fully leverage the energy, agriculture, and technology resources of the United States, Congress must be prepared to react to a new and dynamic energy market for aviation fuel.

ABOUT THE C2ES SUSTAINABLE AVIATION FUEL TECHNOLOGY WORKING GROUP

In October 2023, C2ES established the Sustainable Aviation Fuel Technology Working Group to address the challenge of accelerating emerging SAF technologies. This group has regularly convened leading experts representing current and prospective SAF producers, airlines, energy providers, transportation infrastructure and logistics experts, investors, and corporate buyers of SAF. Recognizing the diversity of feedstocks and pathways capable of producing SAF, the working group supports the production of all forms of low-carbon SAF, with a particular focus on emerging technologies that have yet to reach established production capacity, such as alcohol-to-jet SAF and e-SAF (also known as power-to-liquid SAF).

Over the past year, the working group has leveraged the collective knowledge and experiences of stakeholders to define the following barriers to commercialization and adoption of SAF under current conditions, ranked roughly in order of relevance by participants:

- There is a gap between the price producers must charge for SAF and the price airlines will pay beyond certain volumes.
- The demand for up-front capital required to commercialize a single plant exceeds accessible private and/or public capital.
- The demand for electrical grid and fuel infrastructure development in support of SAF production exceeds the financial and technical capacity of fuel producers to address.
- The demand for power-to-liquid (PtL) feedstocks (i.e., carbon dioxide, hydrogen, and clean energy) and advanced biogenic feedstocks (e.g., inedible matter from crops, certain industrial wastes and residues) exceeds the extent to which they can currently be utilized at an acceptable financial cost.
- The anticipated global supply of SAF by 2030 is insufficient for airlines and other offtakers to meet their procurement/climate goals, regardless of cost.

ON INNOVATION

Policymakers must play a central role in accelerating innovation in SAF production. The key objective of policy for SAF innovation should be cost reduction, since SAF performs similarly to conventional jet fuel. If the cost differential between SAF and fossil-based fuel were to remain large, aviation industry stakeholders would likely be deterred from trying to substantially reduce their greenhouse gas emissions, as the primary manner the industry can decarbonize is via fuel switching. Cost reduction is a particularly important objective for the least carbon-intensive SAF with the most sustainable supply of feedstocks, which offers the greatest emissions-reduction benefits in the long run. A holistic policy framework would need to encourage continual improvement of SAF production technologies and would encompass their full lifecycle from research and development through demonstration and early deployment (see Figures 2 and 3). The framework must thread the needle between multiple complex dynamics: balancing supply- and demand-side incentives so that the SAF market grows steadily while the cost differential declines; managing pressure on existing feedstocks while developing new ones; and collaborating internationally in this intrinsically global industry while ensuring that a secure, affordable supply of domestic SAF emerges. The first year of the SAF working group involved a detailed exploration of these dynamics.

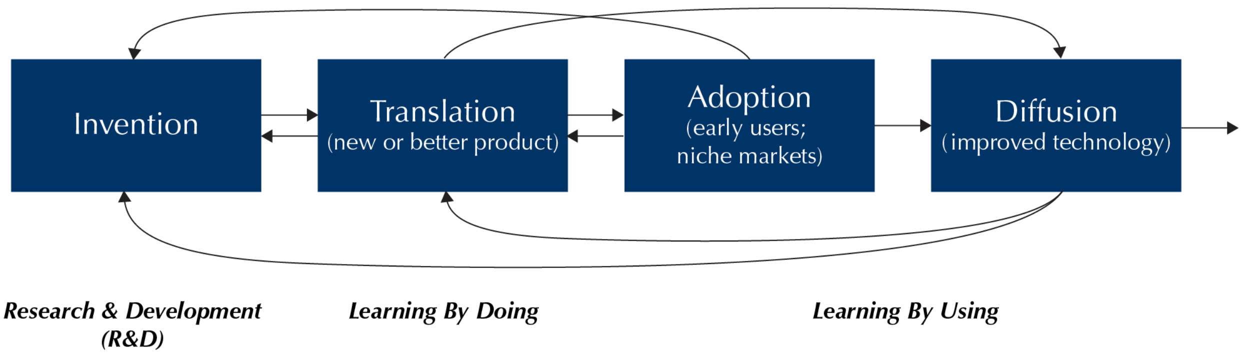
C2ES will continue to build on this work, integrating learnings from other technology working groups (i.e., long-duration energy storage, clean hydrogen, and engineered carbon removal), and helping to align each technology ecosystem around a vision for innovation that can effectively and responsibly speed the commercial deployment of this critical set of technologies.

FIGURE 2: Project Stages of a New Innovation

As an innovation is developed and evolves, it moves through different stages before achieving commercial deployment and widespread diffusion. Throughout these stages, different feedback loops of the innovation process are triggered, helping enable continuous improvement.

Process graphic adapted from: David Yeh, "From FOAK to NOAK", *CTVC by Sightline Climate* (blog), April 19, 2024, https://www.ctvc.co/from-foak-to-noak/?ref=ctvc-by-sightline-climate-newsletter.

FIGURE 3: The Innovation Process



The innovation process is made up of four interrelated stages: invention, translation, adoption, and diffusion. From ITIF: "Programs and policies across these stages shape a complicated innovation ecosystem that includes a diverse network of institutions. Few technologies move from research to market in a linear fashion. Most are aided by feedback from later stages to earlier ones, so that downstream learning is incorporated into design and development."

Source: Jetta L Wong and David Hart, "Mind the Gap: A Design for a New Energy Technology Commercialization Foundation" ITIF, May 2020, https://d1bcsfjk95uj19.cloudfront.net/sites/default/files/2020-mind-gap-energy-technology.pdf.

OVERVIEW OF POLICY RECOMMENDATIONS

C2ES has produced the following shortlist of high-impact policy recommendations based on discussions over the first year of the working group. These recommendations are focused on specific actions the federal government can take to help unlock widespread adoption of a diverse, low-carbon fuel mix in the aviation sector, and fall into four categories: tax credits, market-based credits, financing, and carbon pricing. Table 1 summarizes the legislative and administrative policy priorities outlined in this brief.

TABLE 1: Summary of Policy Priorities

CATEGORY	POLICY PRIORITY	LEAD
Tax credits	Extend tax credits for SAF production	L A
Market-based credits	Update the Renewable Fuel Standard	L A
Financing	Fund additional demonstration and pioneer production projects	L A
Carbon pricing	Enact federal economy-wide carbon pricing and authorize the implementation of the Carbon Offsetting and Reduction Scheme for International Aviation	L A

The column labelled "leads" indicates whether the policy falls under federal legislative L and or federal administrative A purview.

1. EXTEND TAX CREDITS FOR SAF PRODUCTION

SUMMARY

Congress should extend production-based tax credits, inclusive of a floor price, to cover at least 10 years from when a SAF production facility is placed in service. Existing tax credits are only available for a short period of time and the value of each credit is uncertain. The 40B Sustainable Aviation Fuel Credit is only available for SAF produced in the years 2023 and 2024. The 45Z Clean Fuel Production Credit will only be available for three years (2025–27). Furthermore, tax credits should apply a floor value for SAF which meets minimum emission reduction requirements and provides a more certain return on investment.

RATIONALE

Production-based tax credits ameliorate two key challenges for scaling SAF: they can make SAF more cost-competitive, and they reduce long-term investment risk in new, capital-intensive production facilities. The credits are based on output, meaning that a facility must be operational and producing fuel to claim the tax relief afforded under 40B and 45Z. Any SAF produced after the expiration of 45Z will go uncredited. Considering the 5–7 years that may be required to develop an advanced SAF production facility, the combined 5-year duration of the 40B and 45Z tax credits falls well short of providing the predictable financial conditions needed to compete in an emerging international market.[16] In other words, SAF facilities planned after the enactment of these tax benefits will have few, if any, years of credit-eligible production and are unlikely to obtain the same financing conditions and offtake agreements that would otherwise be accessible with access to these credits for a meaningful duration. To unlock private capital in support of local economies and innovative energy infrastructure, this reduced tax burden must accommodate the timelines required to plan, finance, permit, and construct new facilities.

Extending the eligibility period of SAF tax credits to 10 years following the date a facility is placed into service would provide the economic certainty to reduce investment risk and scale advanced SAF production methods toward technological maturity and economies of scale. This is the duration already afforded to the 45V Credit for Production of Clean Hydrogen and the 45Y Technology Neutral Production Tax Credit, which similarly seeks to support nascent technologies in their advancement toward commercial success.[17]

The amount of credit available is also an important consideration in addressing the current gap between the minimum selling price of SAF and fuels competing for the same market or feedstocks (i.e., fossil jet fuel, ethanol, and renewable diesel).[18] The 40B and 45Z credits set comparable eligibility thresholds for SAF starting at about half of the lifecycle emissions of petroleum jet fuel.[19] Both credits increase their values linearly based on emissions performance with $1.75 per gallon for any SAF achieving zero lifecycle emissions.[20] However, while the value of 40B ranges between $1.75 and its floor value of $1.25, 45Z applies no floor value. The result for 45Z is a steeper decline in credit value between 100 percent and 50 percent emissions improvements. By comparison, this means that SAF with half the lifecycle emissions of petroleum jet fuel would claim $1.25 per gallon under 40B, but only $0.11 under 45Z.[21] Absent a reasonable price floor, the credit value can be effectively negligible despite significant carbon intensity achievements.

INNOVATION LENS

While research, development, and demonstration will provide valuable insights and help overcome bottlenecks, cost-reducing innovations will not emerge fully without commercial-scale SAF production. The construction and operation of commercial-scale plants in the SAF value chain will allow the builders and producers to see opportunities and develop practices that are not evident at smaller scales. This learning-by-doing may create momentum for further innovations in a virtuous cycle, as lower costs expand demand and revenue. But SAF is a capital-intensive industry. To initiate such a cycle, several commercial-scale plants, each costing hundreds of millions of dollars or more, will need to be erected. Private investors will not risk that much money without a reasonable prospect of a satisfactory return. Longer-lasting tax credits with a price floor raise the probability that investors will perceive the investments as worth the risk. Tax credit reform would also stabilize the investment environment, enabling follow-on plants to be built after the first wave proves itself.

IMPLEMENTATION

Congress should enact production-based tax credits to cover at least 10 years from when a SAF production facility is placed in service. This can be achieved by extending the SAF provisions of the 45Z Clean Fuel Production Credit when addressing the 2025 expiration of the Tax Cuts and Jobs Act. In doing so, Congress should also establish a floor value for 45Z-eligible SAF similar to the $1.25 established under 40B.

2. UPDATE THE RENEWABLE FUEL STANDARD

SUMMARY

The Renewable Fuel Standard (RFS) should be updated to ensure the eligibility of e-SAF (i.e., power-to-liquid) as a renewable fuel and allow producers to account for lifecycle emissions reductions from the deployment of carbon capture technology. The implementation of these updates would improve the fitness of the RFS to properly accommodate and fairly credit the production of SAF in the absence of a technology-neutral Clean Fuel Standard (CFS) (see Box 2).

RATIONALE

The RFS program was created under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007. The program, administered by the Environmental Protection Agency (EPA), sets annual volume targets for eligible renewable fuels. Refiners and importers of gasoline and diesel fuel meet annual obligations tied to those targets by generating credits (i.e., Renewable Identification Numbers, or "RINs") from the production of eligible renewable fuels or by purchasing those RINs from other producers. Petroleum-based jet fuel producers do not accrue annual obligations under the RFS; however any SAF that meets the definition of "renewable fuel" is eligible to generate RINs on an opt-in basis. Credit generation under the RFS is an important source of revenue for SAF producers and can help reduce the current cost gap between SAF and competing fuels such as petroleum-based jet fuel and renewable diesel, the latter of which are also credited RINs. Importantly, neither e-SAF nor SAF that meets lifecycle emissions requirements due to carbon capture are eligible to produce RINs, eliminating a vital revenue generation mechanism.

E-SAF as an eligible renewable fuel

E-SAF is an emerging class of SAF. It is produced with hydrogen (derived from clean electricity and water) and carbon dioxide as feedstocks. When made from clean hydrogen and biogenic carbon dioxide (e.g., carbon dioxide from ethanol fermentation), e-SAF can reduce greenhouse gas emissions by 90–108 percent compared to fossil fuels.[22] As other major economies are setting targeted policies to scale e-SAF fuel production, the lack of clear eligibility to generate credits under the RFS is a highly counterproductive disadvantage for e-SAF production in the United States.[23]

Eligibility to generate credits under the RFS is limited to "renewable fuels," which is defined as a "fuel that is produced either from renewable biomass or from a biointermediate produced from renewable biomass" and used to "replace or reduce the quantity of fossil fuel present in a transportation fuel."[24] SAF that is not produced from renewable biomass or biointermediates therefore does not qualify. E-SAF's qualifications under these definitions remain unclear without revised guidance from the EPA or Congress. Furthermore, e-SAF producers who also make e-gasoline or e-diesel products (which are similarly not recognized as "renewable fuels") as part of their fuel slate are considered obligated parties under the RFS who must acquire RINs based on the volume of gasoline and diesel produced. The EPA has clear authority to establish an eligibility pathway for e-fuels produced from biogenic carbon dioxide under the statutory language of the RFS. Congress can further expand eligibility under the RFS by crediting fuels produced from clean hydrogen or non-biogenic carbon dioxide (e.g., carbon dioxide captured from point sources or from direct air capture).

BOX 2: A note on Clean Fuel Standards

In addition to the above recommendations, C2ES supports a technology-neutral Clean Fuel Standard (CFS) which credits SAF and other clean transportation fuels based on lifecycle greenhouse gas performance.* The inclusion of SAF as an opt-in or mandated fuel (e.g., SAF sub-target) under a federal CFS was a topic of considerable discussion amongst SAF working group participants.

In June 2024, C2ES launched a broader policy campaign in support of a federal CFS. C2ES will continue to convene experts to examine the role of jet fuel under a prospective clean fuel standard through the campaign and the continuation of this SAF Technology Working Group. Subsequent learnings and recommendations will be provided separately from the recommendations produced above.

* Center for Climate and Energy Solutions (C2ES), Reaching for 2030: Climate and Energy Policy Priorities, (Arlington: VA: C2ES, 2023), *https://www.c2es.org/wp-content/uploads/2023/03/reaching-for-2030-climate-and-energy-policy-priorities.pdf.*

Lifecycle emissions using carbon capture

There are four categories of fuel pathways under the RFS, each with their own type of RIN (i.e., renewable fuel, advanced biofuel, biomass-based diesel, and cellulosic biofuel). Each category has its own annual volume and lifecycle greenhouse gas emissions requirement, whereby RINs with stricter emissions requirements can be used to satisfy volume requirements of other categories. The advanced biofuel category, for example, includes renewable fuels other than ethanol derived from cornstarch that has lifecycle greenhouse gas emissions that are at least 50 percent less than the petroleum baseline. The emission reduction threshold for the renewable fuel category is significantly lower, at 20 percent. RINs issued from the advanced biofuel category are generally more valuable than RINs issued from the renewable fuel category because they can be used to meet volume obligations under either. It is therefore in the interest of SAF producers to demonstrate the 50 percent emissions reductions required to qualify under the advanced biofuel category.

Carbon capture and sequestration (CCS) from the ethanol fermentation process has the potential to completely negate direct greenhouse gas emissions from the ethanol refining process.[25] For SAF that uses ethanol as a feedstock, these additional reductions may be necessary to achieve 50 percent emissions reductions compared to a petroleum baseline required to be eligible in the advanced biofuel category. Currently, the 40B Sustainable Aviation Fuel Credit lifecycle emissions model recognizes the importance of CCS as it allows SAF producers to apply reductions attributable to carbon capture and sequestration from the corn ethanol fermentation process.[26] However, this option is not available under the RFS, meaning that SAF producers who may demonstrate 50 percent reductions under the 40B credit may not be able to achieve that same threshold under the RFS in pursuit of higher-value RINs. The EPA should permit carbon capture deductions for SAF in a manner similar to the rules under the 40B credit to properly incentivize emissions reductions and domestic production of SAF.

INNOVATION LENS

An updated RFS would expand demand for ethanol-based and e-SAF. This demand pull could help advance innovation for these SAF pathways. The scale of this new demand, and thus its impact on innovation, will depend on the volume of RINs that the policy creates for each pathway. Ethanol production with carbon capture and sequestration is being demonstrated in dozens of locations in North America, but the technology to convert ethanol into SAF is just reaching commercial scale.[27] Expanded demand for this type of SAF might allow the construction of follow-on projects that incorporate learning-by-doing and scale economies from the first-of-a-kind plants, lowering their costs. E-SAF production is less mature, so a smaller volume of new demand would support innovation on this pathway by enabling investment in pilot or demonstration-scale facilities. As each new scale is attained, opportunities that are not available at smaller scales are likely to be revealed, including process modifications that enhance system integration and enable greater efficiency. RFS credit reform could help to solve the chicken-and-egg conundrum of SAF production: innovation depends on demand growth, but market-based demand for SAF depends on the lower costs enabled by these innovations.

IMPLEMENTATION

E-SAF as an eligible renewable fuel

Within its current authority, the EPA should amend RFS regulations in Title 40 Code of Federal Regulations (CFR) 80.2 to define the phrase “produced from renewable biomass” with the meaning that the mass or energy in the finished fuel were sourced from renewable biomass, as previously contemplated in the proposed Renewable Fuel Standards for 2023, 2024, and 2025.[28] This definition is inclusive of e-SAF which may derive mass from renewable biomass (e.g., biogenic carbon dioxide), but not energy (which is sourced from the clean electricity used to produce the hydrogen feedstock). The same definition would permit e-SAF with hydrogen produced from the energy of renewable biomass (e.g., hydrogen produced from electricity generated from biogas) to qualify. Upon establishing this definition of “produced from renewable biomass,” the EPA should amend the definition of “biointermediate” in 40 CFR 80.2 to include “biogenic carbon dioxide” to provide certainty to e-fuel producers that fuel produced from biogenic carbon dioxide is a renewable fuel (and can therefore generate revenue from RINs).

Separately, the administration and Congress should examine options and work toward expanding the RFS beyond renewable fuels produced from biomass (and ensure that EPA is properly resourced to process new pathway applications). Amendments to the RFS under 42 U.S. Code (U.S.C.) § 7545(o)(2) should prioritize the inclusion of technology- and feedstock-neutral low-carbon fuels including fuels produced from clean hydrogen and non-biogenic carbon dioxide. Congress should develop policy principles, draft amendments, conduct workshop discussions, and hold committee hearings to maximize stakeholder input and minimize market distortions. Congress should also analyze the additive value of the RFS if a federal CFS is implemented in a way that similarly incentivizes clean transportation fuels.

Lifecycle emissions using carbon capture

The EPA should propose new rules to allow SAF producers to receive credit for CCS in the production of ethanol feedstocks in the determination of SAF lifecycle emissions. Notably, while statutory definitions under the Energy Independence and Security Act of 2007 prohibit corn starch ethanol itself from qualifying as an "advanced biofuel" regardless of its lifecycle emissions, this restriction does not prevent SAF—which may use corn ethanol as a feedstock—from qualifying.

In proposing new rules under the RFS for crediting carbon capture technology, the EPA should propose similar deduction methods permitted under the 40B tax credit (or future versions thereof, including the 45Z Clean Fuel Production Credit). The EPA should likewise propose an accounting method that recognizes the utilization of captured carbon dioxide, in addition to its permanent sequestration, to support the use of biogenic carbon dioxide as a feedstock in the production of e-fuels.

3. FUND ADDITIONAL DEMONSTRATION AND PIONEER PRODUCTION PROJECTS

SUMMARY

Congress should provide additional funding and support to first-of-a-kind and demonstration SAF production facilities to accelerate the commercialization of advanced SAF pathways. In doing so, Congress should provide annual funding to the Fueling Aviation's Sustainable Transition discretionary grant program (FAST-SAF) and provide additional resources to the Department of Energy (DOE) in support of grants under the Bioenergy Technologies Office (BETO). A SAF-specific funding pool should be created for SAF-related loans and loan guarantees under the agency's Loan Programs Office (LPO).

RATIONALE

Growing domestic SAF production beyond 2030 goals will require unprecedented scaling of newer production methods that are currently at low to moderate technology readiness levels.[29] Facilities using more advanced SAF production technologies than HEFA and co-processing—like alcohol-to-jet and e-SAF production—face steep financing challenges due to their perceived investment risk profiles. The launch of demonstration and first-of-a-kind projects is an invaluable step toward proving the technical and operational viability needed to unlock private investments.

Considering the estimated $30 billion of capital investments that could be required to build out the production and delivery infrastructure to meet the U.S. goal of producing 3 billion gallons of SAF by 2030, unlocking private sector investments by strategically derisking technologies through demonstration and pioneer projects must be a priority.[30] The FAST-SAF Program is a one-time $244 million discretionary grant program administered under the FAA for projects relating to the production, transportation, blending, and storage of SAF. In August 2024, the FAA announced award selections that allocated the full program funds across 22 SAF projects, including those planning to produce SAF through advanced PtL and AtJ pathways.[31] Providing funding to the FAST-SAF Program on an annual basis would enable earlier development of commercially viable projects and mobilize private capital for SAF production and distribution infrastructure. Similarly, Congress should provide the DOE with additional funding to increase support for SAF-related projects at BETO, as requested in the Department of Energy FY 2025 Budget in Brief.[32] BETO's mission to "develop and demonstrate technologies to accelerate reduction of greenhouse gas emissions through the cost-effective, sustainable use of biomass and waste feedstocks across the U.S. economy" positions it to continue partnering with SAF producers to advance demonstration-stage projects toward BETO's strategic goal to produce cost-effective SAF.[33] Notably, as FAST-SAF funding applies only to pathways approved by ASTM International, BETO plays an important role in supporting more novel technologies that have not yet been accredited.

Beyond the provision of grants, Congress should ensure that the DOE LPO is resourced to provide loan guarantees for commercial-stage SAF projects under the Innovative Energy Programs category of the LPO's Title 17 Clean Energy Financing Program. In doing so, Congress should consider ways to improve the accessibility of LPO financing for SAF producers. Prospective loan recipients cite long timelines for project vetting, low appetite for risk, and restrictive loan terms as key barriers. Congress should address these barriers by pursuing changes to lending terms with the objective of providing a distinct advantage over, and mobilizing additional, private sector financing. Restrictions that exacerbate these issues include subordination restrictions, which create unfavorable conditions for mobilizing private sector investors by prioritizing repayment to the government; "denial of double benefit" restrictions, which prohibit federal grant recipients from applying for loan guarantees; and a lack of an explicit focus or mandate on sustainable aviation fuel as an eligible project category. Legislating greater agency discretion on subordination restrictions and denial of double benefit provisions would allow flexibility where strict adherence is counterproductive to technology development. For example, while denial of double benefit may advance the public interest to prevent excessive or wasteful funding of the same project under different programs, it may also disallow loans needed to operationalize new production technologies developed with the help of government research grants.

INNOVATION LENS

Demonstration is a vital phase of the innovation process for SAF production pathways that have not reached commercial scale. The process of building and running a demonstration project will produce insights that can help lower costs and improve performance of similar future projects. However, demonstration projects, particularly first-of-a-kind projects, are risky and difficult to finance from private investors. The risks include technology that fails to function as designed, management that fails to meet cost and schedule targets, and anticipated customers who prefer alternatives. A large body of evidence suggests that public investment is crucial to bridge this "demonstration valley of death."[34] If second-, third-, and nth-of-a-kind projects using the same advanced SAF pathway were to be included in the demonstration portfolio, the learning benefits could spill over to their feedstock and equipment supply chains as well. Each iteration reduces the risk for the next one, which may allow the public share of investment to decline and enable a shift in this investment from grants to loans. Such "blended" financing would stretch limited public dollars across more projects. In the long run, the learning process triggered by publicly supported demonstration projects (and supported by other downstream policies, like tax incentives) should allow SAF producers to gain access to conventional, lower-cost project financing.

IMPLEMENTATION

Congress should work with FAA and DOE officials to analyze applications received under the FAST-SAF and BETO grant programs pertaining to SAF to better understand the level of resources required to meet market demand. Congress should use these findings to inform the amount of additional funding and support needed for demonstration and first-of-a-kind SAF production facilities to accelerate the commercialization of advanced SAF pathways through those programs and offices. In doing so, Congress should provide annual funding to the Fueling Aviation's Sustainable Transition discretionary grant program (FAST-SAF) and provide additional resources to the Department of Energy (DOE) in support of grants under the Bioenergy Technologies Office (BETO).

Congress should pursue several changes under the DOE LPO to make it more accessible to SAF producers. Eligible project categories under 42 U.S.C. § 16513(b) should be amended to explicitly list SAF technologies as eligible recipients of loan guarantees.[35] Congress should appropriate additional funds to accommodate expected guarantees under this new project category. Congress should amend the repayment provisions under 42 U.S.C. § 16512(d) to remove the unilateral subordination requirement and instead instruct the Secretary to establish guidance that dictates the limited circumstances under which those terms should be included.[36] Congress should also amend the denial of double benefit provision under Section 50141(d) of the Inflation Reduction Act and likewise instruct the Secretary to establish guidance under which projects that currently fall under the provision may be exempt, for example depending on the use of, or duration between, those funds.[37]

4. ENACT FEDERAL ECONOMY-WIDE CARBON PRICING & AUTHORIZE THE IMPLEMENTATION OF THE CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION

SUMMARY

The administration and Congress should examine options and work toward enacting an economy-wide market-based carbon pricing program that would contribute to the achievement of net-zero emissions by 2050. Revenue generated from a carbon price could in part be used to support SAF specifically, or for other purposes such as lowering government deficits or reducing taxes. Separately, Congress should confer to the U.S. Department of Transportation the authority to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) in the United States, requiring that U.S. airline operators monitor and report international aviation emissions under the FAA CORSIA Monitoring, Reporting, and Verification (MRV) Program and compensate for their emissions growth as required under the CORSIA program.

RATIONALE

Federal economy-wide carbon pricing

A carefully designed, economy-wide carbon pricing program would facilitate emissions reductions where they are most cost-effective. Setting a price on carbon—whether through a carbon tax or cap-and-invest program—enables businesses to make decisions commensurate with the environmental, societal, and economic benefits of reducing global greenhouse gas pollution.

Widespread adoption of low-carbon aviation fuel requires addressing the market disadvantage for SAF compared to cheaper petroleum jet fuel.[38] While this can and should be addressed by targeted support of SAF through different incentives programs, it is also true that the market today does not reflect the full costs of petroleum jet fuel and its greenhouse gas pollution.[39] Carbon pricing applied to fossil fuel production would further reduce the cost gap between SAF and petroleum jet fuel.[40] The long-term and predictable costs of a carbon pricing policy would reduce investment risk in advanced SAF production methods, feedstock supply chains, and in other aviation technologies designed to reduce fossil fuel consumption like more efficient aircraft designs. Congress should carefully consider the scope, design (e.g., flexibility and cost containment mechanisms), and revenue allocation options to implement effective price signals while mitigating any excessive burden on consumers and "hard-to-abate" sectors, including aviation.

Authorization to implement CORSIA

The International Civil Aviation Organization (ICAO) CORSIA is an internationally agreed market-based measure designed to offset emissions from international flights above 2019 levels. Under the program, airline operators from participating countries monitor and report their international flight emissions to the relevant authority (e.g., FAA in the United States) and meet any corresponding offsetting requirements by purchasing eligible carbon credits. Operators may reduce their offsetting obligations by purchasing SAF certified to ICAO's standards. The standards, lifecycle emissions methodologies, and sustainability frameworks developed under ICAO's Committee on Aviation Environmental Protection to implement CORSIA have been valuable technical resources from which individual countries have based their own regulatory frameworks for SAF. While the United States has committed to participate in the first two voluntary phases of CORSIA (i.e., 2021–23 and 2024–26), Congress has not yet authorized the U.S. Department of Transportation or the FAA to implement the program. Without this authority, the FAA has thus far relied on the elected participation of operators to report airline emissions under the FAA CORSIA MRV Plan and has no authority to require airlines to surrender offsets under this program.[41] Failing to authorize the implementation of CORSIA would undermine both the CORSIA program that the United States played a major role in developing and the international standing and leadership of the United States. Consequently, a patchwork of regulations from individual countries aimed at emissions from international flights may take its place.[42] Conversely, successful implementation of CORSIA would incentivize reduced emissions from international flights and operationalize an additional source of demand for SAF, albeit one that is heavily dependent on the availability of cheaper carbon credits to satisfy emissions obligations.[43]

INNOVATION LENS

A carbon price would narrow the cost differential between SAF and conventional jet fuel, speeding the pace of adoption. It could impact all phases of the innovation process, especially when combined with policies that reduce the cost of SAF. Potential investors in SAF research, development, demonstration, and deployment will perceive that it will become increasingly competitive, particularly if the carbon price rises predictably over time. If some of the revenue generated by this policy were directed to federal support of SAF research, development, and demonstration, program managers could target these resources to any pressing innovation challenge facing the industry. While it will take time before the aviation fuel market responds to the carbon price with a significant volume of SAF purchases, the demand signal the price provides will be crucial to meet long-term climate goals. Implementation of CORSIA would also send a demand signal across the SAF value chain. As with a carbon price, this signal is likely to be weak initially, as other offsets are used to meet CORSIA obligations, but it should become stronger as the program becomes better-established and SAF prices grow more attractive.

IMPLEMENTATION

Federal economy-wide carbon pricing

The administration and Congress should examine options and work toward enacting an economy-wide market-based carbon reduction program that could contribute to the achievement of net-zero emissions by 2050. The program should be designed to implement a price for greenhouse gas emissions, based on policy principles that prioritize science-based emissions reductions, technology-neutral approaches, and economic health. Analyses should consider carbon abatement costs and price sensitivities across economic sectors and the development and availability of emissions reduction technologies.

Following the U.S. Supreme Court overruling the Chevron doctrine, congressional proposals should directly address which sources of greenhouse gas emissions should be included within the carbon pricing program (i.e., clearly include emissions related to petroleum production), provide guidance to an authorized agency on how emissions should be calculated and priced, and determine how revenue may be allocated.[44]

Authorization to implement CORSIA

Congress should authorize the U.S. Department of Transportation to implement global market-based measures under the ICAO CORSIA. Authorization should take place before the first mandatory phase of CORSIA commences in 2027, which necessitates Congressional action before FAA's five-year reauthorization expires after 2028.

CONCLUSION

The U.S. federal government has reinforced its global leadership in energy production, aviation, and innovation by setting ambitious goals to produce three billion gallons of SAF by 2030 and 35 billion gallons by 2050. Existing federal programs, such as tax and market-based credits, government grants, and access to loan guarantees are foundational to scaling domestic SAF production. Despite these existing federal programs, significant barriers remain to scaling SAF in the United States. The cost of SAF remains high relative to conventional jet fuel and there are gaps in accessible up-front capital for commercial SAF plants. Continuous improvement of existing programs and thoughtful additions of new initiatives will be essential for the United States to adopt a diverse, low-carbon fuel mix in its aviation sector. These efforts are also vital for maintaining the nation's competitive edge in the emerging global SAF market. The policy recommendations offered in this brief were developed through discussions with stakeholders across the SAF ecosystem and offer a potential path forward in the pursuit of this objective. Congress and the administration should (1) extend tax credits for SAF production; (2) update the RFS; (3) fund additional demonstration and pioneer production projects; and (4) enact federal economy-wide carbon pricing and authorize the implementation of CORSIA to build a robust domestic SAF supply as a critical component of a broader decarbonization strategy.

ACKNOWLEDGEMENTS

C2ES thanks the following companies and organizations for their participation in discussions informing these policy recommendations. A company's participation does not represent an endorsement of the full contents of this brief. As a fully independent organization, C2ES is solely responsible for its positions, programs, and publications.

AIR COMPANY	Gevo, Inc.	SkyNRG
Airlines for America	HeatPath Solutions	Topsoe
American Airlines Group, Inc.	Infinium	Twelve
Arcadia eFuels	LanzaJet	United Airlines, Inc.
Council on Sustainable Aviation Fuel	Marquis Inc.	Velocys, Inc.
eBay, Inc.	RMI	World Energy, LLC
Equitable Energy Ventures, LLC	Shell USA, Inc.	Zero6 Energy, Inc.

This brief was developed by C2ES and the underlying policy recommendations were prepared by C2ES's Sustainable Aviation Fuel Technology Working Group Team: John Holler, Diandra Angiello, Johanna Wasserman, Doug Vine, and Jason Ye. The policy brief also benefited greatly from the insights and contributions from: David Hart, Brad Townsend, and Nat Keohane.

Additional Resources

Sustainable Aviation Fuel Working Group (Webpage)
https://www.c2es.org/accelerating-the-us-net-zero-transition/c2es-technology-working-groups/sustainable-aviation-fuel

SAF Tech Working Group identifies four policies needed for takeoff (Blog)
https://www.c2es.org/2024/12/saf-tech-working-group-identifies-four-policies-needed-for-takeoff

Scaling Sustainable Aviation Fuel: Recommendations to Federal Policy Makers from Washington State (Brief)
https://www.c2es.org/document/scaling-sustainable-aviation-fuel-recommendations-to-federal-policy-makers-from-washington-state

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1400 K ST, NW STE 1100 WASHINGTON, D.C. 20005 703-516-4146 C2ES.ORG