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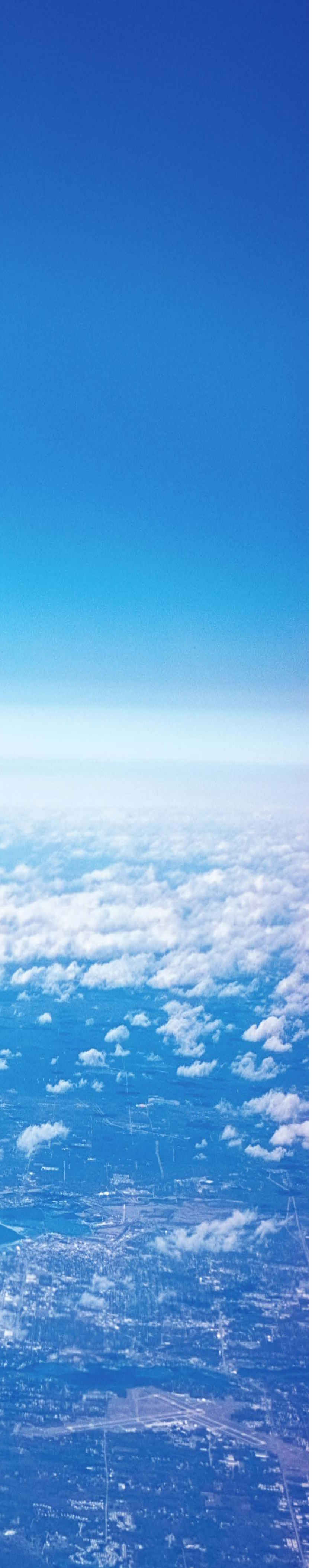
Sustainable Aviation Fuel Policy in the United States: A Pragmatic Way Forward

by Fred Ghatala



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Cover: Lake Michigan's shoreline seen from an airplane. Unsplash/Simon Maage

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Executive Summary

UNSPLASH/SUNYU KIM

Aviation's current reliance on fossil fuels, its expected continued growth rate following the COVID-19 pandemic, the service lifespan of aircraft, and the lack of non-liquid fuel alternatives make it a challenging sector to decarbonize, especially compared with ground transportation. However, there is an opportunity to invigorate Sustainable Aviation Fuel (SAF) production and use through pragmatic, sector-specific policy, which could play a significant role in decarbonizing the sector.[1]

Currently, SAF is largely included as an add-on to existing renewable fuels policies that focus on addressing emissions from ground transportation. In this context, SAF is challenged to compete with other renewable fuels. This is partly due to its relatively recent emergence compared with other renewable fuels, the fact that it sells into a voluntary (rather than obligated) aviation fuel market, and that it receives fewer incentives.

Policies that focus on lowering the carbon footprint of liquid fuels in the transportation sector, as opposed to policies that focus on lowering economy-wide emissions, give more GHG reduction credits to biodiesel and renewable diesel than SAF due to SAF's marginally higher lifecycle CO_2 emissions, for some conversion technologies and plant configurations.[2] SAF's underlying production economics are more challenging than those of other renewable fuel types because, per unit of feedstock, current technologies typically yield less fuel, require more energy inputs, and have fewer recognized avoided greenhouse gas (GHG) emissions. If renewable fuels were the only option for lowering the carbon footprint of the entire transportation sector, decarbonization policies would aim to produce the optimal emissions-reduction outcome, which would likely allocate renewable content primarily to ground and maritime transportation, with limited fuel for aviation. However, with fuel switching options for ground and maritime transportation more readily available, and with aviation largely excluded under current transportation-sector GHG policies, the current approach misses opportunities for emissions reductions in aviation. Furthermore, additional environmental co-benefits from SAF are well documented, including conventional air pollutants,

1 Sustainable Aviation Fuel (SAF) is defined as a certified, drop-in, distillate fuel that satisfies jet fuel form, fit, and function requirements, while meeting sustainability standards applicable in the relevant jurisdiction.

2 Matthew Pearlson, Christoph Wollersheim, and James Hileman, "A techno-economic review of hydroprocessed renewable esters and fatty cids for jet fuel production," *Biofpr* 7:1 (2013), 89–96, https://onlinelibrary.wiley.com/doi/abs/10.1002/bbb.1378.

reduced contrail formation, and reduced black carbon emissions compared to fossil jet fuel.[3] Developing research suggests that—in addition to GHG reduction—SAF provides a range of other climate change mitigation benefits as well.

Displacing conventional, petroleum-based aviation fuel with SAF is the primary area in which substantial gains can be made to mitigate aviation's emission growth directly. Therefore, SAF merits specific policy treatment due to aviation's forecast growth rate, the lack of available alternative fuel types (e.g., the limited expected penetration of battery-powered and hydrogen fuelled aircraft), and the large opportunity SAF presents to address aviation emissions through sector-specific expansion of low carbon fuel production. Furthermore, SAF will not be effectively enabled through broad, generic renewable fuel production incentives. It needs specific, targeted policies that can address its unique circumstances.

Airlines and other aviation operators have demonstrated their willingness to create demand for SAF through long-term offtake agreements and direct project investment, however, under existing renewable fuel regulations and incentive programs, the current SAF supply is scarce and, as a result, priced at a significant premium to both petroleum jet fuel and other renewable fuels (such as renewable diesel). This report proposes and evaluates a menu of policy options for establishing a viable SAF sector in the United States with an emphasis on policy types with demonstrated utility for helping to establish other renewable energy sectors. The proposed policy options to enable SAF are stable over time, are technology-neutral to encourage diverse production technologies and feedstocks, include stackable incentives linked with environmental performance, enable participation in renewable fuel regulations and compliance credit markets, are promulgated at the national level to avoid pre-emption issues, and are designed with bipartisan support to reduce the risk of political reversal.

This report proposes multiple categories of policy action to accomplish the following:

- **Attract capital to expand SAF supply:** federal programs to attract capital to SAF include loan guarantee programs, establishing SAF eligibility for programs like Master Limited Partnerships, tailoring Investment Tax Credit (ITC) programs to encourage SAF, and a performance-based tax credits similar to 45Q.
- **Assist SAF facility operation:** incentives like the Blender's Tax Credit (BTC), the Producer's Tax Credit (PTC), and excise tax relief would assist project viability and production economics.
- **Recognize SAF environmental benefits through carbon pricing and other systems:** a well-designed carbon price regime would take the positive environmental externalities of SAF into account and help address SAF's price premium. Other programs can recognize SAF's environmental co-benefits, including lower conventional air pollutant emissions and non-CO_2 climate benefits.
- **Create structural SAF demand:** including SAF in existing and future renewable fuel regulations would increase demand through established policy approaches.
- **Demonstrate US government commitment to SAF to encourage project development:** Multiple levels of government and the US military can commit to SAF procurement to reduce environmental impacts of operations and to assist in sector development through long-term contractual purchase. Government can communicate an intent to develop comprehensive SAF policy measures and to further direct research efforts to address barriers to SAF production and use.

The included policy options were reviewed and discussed with select sector stakeholders to incorporate their views into the framing the issues that have hindered SAF development. Efforts in this area will rely on the strength of the advocating group to articulate why limited government resources should be directed towards SAF efforts, rather than a vast number of competing priorities. A clear next step is for SAF project proponents and the broader aviation supply chain to consider which options are the most reasonable to pursue given the prevailing political and regulatory contexts.

3 Ulrike Burkhardt, Lisa Bock, and Andreas Bier, "Mitigating the contrail cirrus climate impact by reducing aircraft soot number emissions," *Nature Partner Journals, Climate and Atmospheric Science*, December 2018, https://www.researchgate.net/publication/328390091_Mitigating_the_contrail_cirrus_climate_impact_by_reducing_aircraft_soot_number_emissions; "Neste MY Renewable Jet Fuel wins award for reduction of black carbon emissions," Neste, May 7, 2019, https://news.cision.com/neste/r/neste-my-renewable-jet-fuel-wins-award-for-reduction-of-black-carbon-emissions,c2804598; and Alternative Jet Fuels Emissions: Quantification Methods Creation and Validation Report, Airport Cooperative Research Program, August 2019, http://www.trb.org/Publications/Blurbs/179509.aspx.

Introduction

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This report builds upon the technical foundation on SAF established in a previous Atlantic Council report, *Ready for Takeoff: Aviation Biofuels Past, Present, and Future*, by David Hitchcock. In that report, Hitchcock provides essential information to define the SAF opportunity and communicate fundamental technical information to create a workable understanding of SAF by policy makers and key stakeholders.[4] Readers will benefit from familiarity with *Ready for Takeoff* prior to reading this report.

For the purposes of this report, Hitchcock's SAF definition is used: "Sustainable Aviation Fuel (SAF) is defined as a certified, drop-in, distillate fuel that satisfies jet fuel form, fit, and function requirements, while meeting verifiable sustainability standards."[5] This report proceeds on the basis that SAF must, by definition, comply with sustainability requirements that are in place within the relevant jurisdiction of production and/or use, whether it be a domestic system or the International Civil Aviation Organization (ICAO) system. These sustainability requirements may broadly pertain to GHG performance, as well as environmental, social, and economic impacts. This report recognizes that different jurisdictions and organizations choose both definitions of sustainability and operationalizing approaches based on their specific circumstances and decision-making processes.

This report argues that, in the absence of transportation-sector-wide decarbonization policies, SAF-specific policies are necessary to enable this technology, which will be crucial to maximize overall transportation GHG emissions reductions. Therefore, the report proposes a menu of policy options for establishing a viable SAF sector in the United States, focused on the enabling policy types with demonstrated usefulness for establishing renewable energy sectors.

The intent of this report is to further advance informed dialogue on reduction of aviation GHG emissions through SAF by:

- identifying the range of policy options for enabling SAF production and use;
- exploring the impact each option can have to advance this sector; and
- identifying implementation approaches through reviewing the options with informed SAF-sector stakeholders.

The report considers future policy options to incentivize SAF production and use, presents options for how this could be approached, and outlines potential advantages and drawbacks for each policy option. This report was informed by views from across the aviation spectrum, including aviation association representatives, SAF producers, and environmental organizations.

4 David Hitchcock, *Ready for takeoff?* Aviation biofuels past, present, and future, Atlantic Council, January 8, 2019, https://www.atlanticcouncil.org/in-depth-research-reports/report/ready-for-take-off-aviation-biofuels-past-present-and-future/.

5 Ibid. This report uses the term Sustainable Aviation Fuel and its acronym, SAF, to encompass the equivalently composed though differently named *aviation biofuel, alternative jet fuel, renewable jet fuel, biojet fuel, or sustainable alternative jet fuel*.

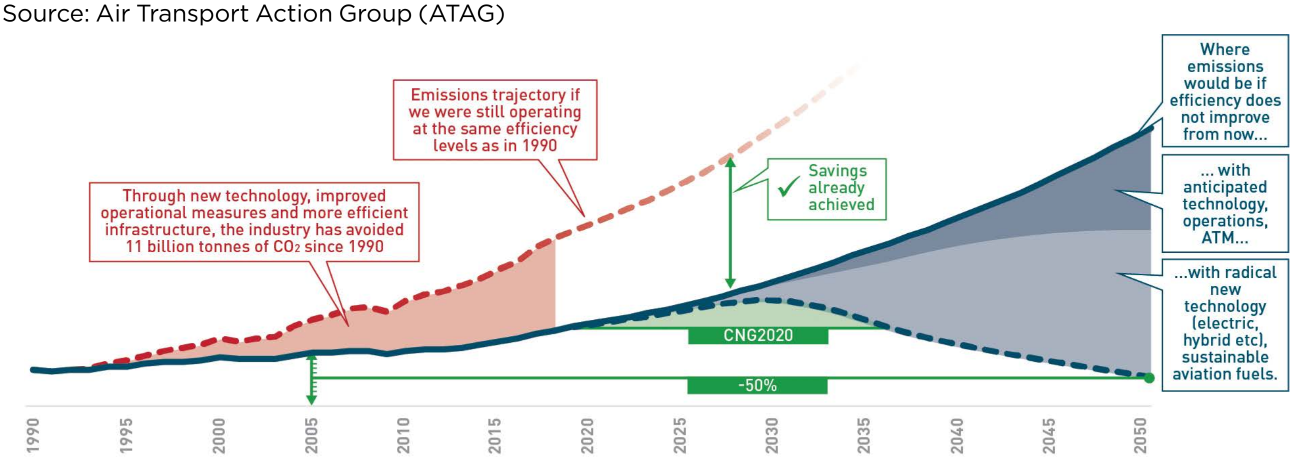
The Sustainable Aviation Fuel Opportunity

There is an opportunity for forward-thinking, pragmatic, and sector-specific policy to invigorate SAF production and utilization to preserve US aviation competitiveness and allow aviation's benefits to endure and expand. Aviation is irreplaceable—it is a fundamental part of our global society, a key contributor to economic development, social progress, and increasing human interaction. It provides the most accessible worldwide transportation network. Amidst increased attention on aviation's growing environmental impact, currently embodied in the Flygskam or 'flight-shaming' movement, the time is ripe to create pragmatic SAF policy.[6]

Prior to the COVID-19 crisis, US carrier domestic passenger growth was expected to average 1.8 percent per year for the next twenty years.[7] While it may take some time for the U.S. economy and air traffic to recover from the negative impacts of the crisis, it is expected that the industry will return to a growth trajectory within a few years. Large-scale SAF use is regarded as an essential component of US aviation's ability to address the GHG emissions growth anticipated in the sector.[8] Current levels of SAF production and use, while important pioneering steps, are yet to establish the scale of production required to meaningfully address the expected emissions growth projected prior to the COVID-19 crisis. Globally, airlines have not established SAF-specific use commitments, though they are incorporated within the broader aviation industry commitments to 1.5 percent annual fuel efficiency improvement through 2020, carbon neutral growth from 2020, and 50 percent net CO_2 reduction by 2050 (relative to 2005 levels). Business aviation has established comparable goals, though, with a 2 percent annual fuel efficiency improvement target that aligns their efforts to enhance aircraft design (including engines, airframes, winglets, and other equipment) and operation. The chart below figuratively represents the 'Business as Usual' scenario and the contribution of different categories of action to address emissions.[9]

As part of a holistic effort to decarbonize the entire transportation sector, SAF is a long-term opportunity to reduce overall global GHG emissions that can be pursued immediately, with immediate impact. SAF benefits from the tremendous work already put into establishing technical feasibility, end-user acceptance, and methodologies to confirm GHG emissions benefit, as well as an informed understanding of existing barriers and how to overcome them.[10] Essentially, what is required to expand SAF production and use is policy leadership.

Figure 1: Indicative International Aviation Targets for Addressing C02e Emissions.
Source: Air Transport Action Group (ATAG)



6 The Flygskam "flight-shaming" movement suggests that people should be embarrassed by the environmental impact of air travel. The term is attributed to Swedish artist Staffan Lindberg.

7 *FAA Aerospace Forecast: Fiscal Years 2019–2039*, Federal Aviation Administration, May 2019, https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2019-39_FAA_Aerospace_Forecast.pdf.

8 Mark D. Staples, et al., "Aviation CO_2 emissions reductions from the use of alternative jet fuels," *Energy Policy* 114 (2018): 342-354, https://www.sciencedirect.com/science/article/pii/S0301421517308224.

9 ICAO releases estimations of global environment trends and the contribution of specific technologies to achieving emissions reductions that are more specific than the ATAG figure. The ATAG figure is useful in displaying both the 2020 and 2050 targets. See: "Working Paper: Assembly—40th Session," International Civil Aviation Organization, May 7, 2019, https://www.icao.int/Meetings/a40/Documents/WP/wp_054_en.pdf.

10 This report does not cover the exhaustive list of barriers already surmounted through concerted hard work of numerous individuals and organizations. Additional information is available via the Commercial Aviation Alternative Fuels Initiative (CAAFI), itself a leader in the development of SAF. See: Commercial Aviation Alternative Fuels Initiative, accessed April 2020, www.caafi.org.

Setting the Scene: Aviation Emissions, Sustainable Aviation Fuel, Enabling Policy

UNSPLASH/AZLAN BAHARUDIN

Aviation's reliance on fossil fuels, its expected future growth rates, and the service lifespan of aircraft make it a difficult section of the transportation sector to decarbonize. The average commercial aircraft has a service lifespan of twenty-five years (with general aviation aircraft having a lifespan of 37.5 years) making it probable that the sector will continue using distillate-type fuels (such as Jet A, Jet A-1) for the next decades.[11]

US aviation, which includes airlines, general and business aviation, and the US military, currently accounts for 2.6 percent of total domestic emissions and 9 percent of the emissions from the broader US transportation sector.[12] Following COVID-19, continued US aviation expansion is expected: the Federal Aviation Administration (FAA) forecasts an increase in US airline passengers from 917 million in 2019 to 1.31 billion in 2039—43 percent growth over a twenty-year period.[13] Over the same period, FAA projects that jet fuel consumption will increase from 24.08 billion gallons to 30.64 billion gallons. While the trajectory of this growth is expected to be delayed in light of the COVID-19 pandemic, over the long run it is expected that growth will return.

At the international level, ICAO, the United Nations (UN) organization with jurisdiction over global aviation, expects the impact from global aviation to more than triple by 2045, absent tremendous adoption of new technology and SAF.[14] Even the benefits from continuing existing gains in fuel efficiency (a 52 percent increase in efficiency from 1990 to 2017) will be outpaced by the sector's growth, leading to an overall emission increase.[15]

ICAO's 2019 Environmental Report analyses the significant role that SAF must play towards achieving carbon neutral growth beginning in 2020 and the challenge ahead to accomplish that target:[16]

> Achievement of carbon neutral growth at 2020 emissions levels out to 2050 would require nearly

11 Jet A is the grade of aviation turbine fuel used in the United States. It has a higher freezing point than Jet A-1, which is the standard fuel used in international travel due to colder operating conditions from higher altitudes and travel over polar regions.

12 "Fast Facts on Transportation Greenhouse Gas Emissions," US Environmental Protection Agency, last updated July 16, 2019, https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.

13 Federal Aviation Administration, *FAA Aerospace Forecast*.

14 International Civil Aviation Organization, "Working Paper."

15 "Fact Sheet #3: Tracking Aviation Efficiency," Climate Action Takes Flight, January 2019, https://aviationbenefits.org/media/166506/fact-sheet_3_tracking-aviation-efficiency.pdf.

16 *2019 Environmental Report: Aviation and Environment*, International Civil Aviation Organization, 2020, https://www.icao.int/environmental-protection/Documents/ICAO-ENV-Report2019-F1-WEB%20%281%29.pdf.

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complete replacement of petroleum-based jet fuel with sustainable alternative jet fuel and the implementation of aggressive technological and operational scenarios. The effort required to reach these SAF production volumes would have to significantly exceed historical precedent for other alternative fuels, such as ethanol and biodiesel for road transportation.[17]

SAF is a conceivable means through which steep aviation GHG growth could be controlled during the span of the current commercial aircraft fleet's operations and the limited time window available to achieve aviation's own emissions goals as established by ICAO. The magnitude of emissions reductions needed to achieve targets make exploring all options to establish greater SAF production necessary.

Airlines are actively pursuing SAF opportunities

Airline leadership, demonstrated through willingness to enter into long-term offtake agreements, has been instrumental in creating SAF demand. SAF is now produced and used on a continuous basis due to airline voluntary product offtake agreements.[18] Globally, more than forty airlines now have SAF experience, with an estimated 200,000 commercial flights using SAF since 2011 and 1.6 billion gallons of SAF committed to forward purchase agreements.[19] Efforts in the business aviation community focus on identifying opportunities to increase SAF production and promoting its use by undertaking SAF flight demonstrations and disseminating technical information in the sector to assist and inform operators.

17 Ibid.

18 A list of SAF offtake agreements is available through CAAFI. See: "CAAFI's Role," Commercial Aviation Alternative Fuels Initiative, accessed April 2020, http://www.caafi.org/focus_areas/end_users.html. Briefly, United Airlines and KLM (Netherlands) are airlines with current offtake agreements and daily SAF use. Fuel is delivered to Los Angeles International Airport (LAX) and San Francisco International Airport (SFO) and is produced by World Energy. Lufthansa, KLM, Finnair, and Jet blue have announced fuel purchase agreements with SAF producer Neste. Future purchase commitments by additional airlines are allowing SAF facilities to proceed with construction. Delta Air Lines and Scandinavian Airline System have signed off-take fuel sale agreements with Gevo, Inc., with the SAF expected to be produced upon completion of an expansion to Gevo's existing advanced biofuel production facility in Luverne, Minnesota. United and Cathay Pacific (Hong Kong) have offtake agreements with Fulcrum (Nevada project location), FedEx and Southwest have offtake agreements with Red Rock Biofuels (Oregon project location). Delta has announced a partnership with Northwest Advanced Bio-Fuels, and Lanzatech and All Nippon Airways (ANA) announced an SAF off-take agreement to begin in 2021.

19 Robert Boyd, "Sustainable Aviation Fuels: Wastes, Resides and Advanced Low Carbon Fuels," PowerPoint presentation, ISCC—Stakeholder Dialogue, Shanghai, July 2, 2019, https://www.iscc-system.org/wp-content/uploads/2019/07/11.-Robert-Boyd_IATA_Sustainable-Aviation-Fuels.pdf; and Commercial Aviation Alternative Fuels Initiative, personal communication with the author.

The impetus for airline SAF purchase and investment may indicate anticipation of operating in a GHG constrained policy environment. Through hands-on experience with securing future SAF supply, airlines may be strategically positioning themselves for increased competitiveness. With any voluntary activity, its durability is dependent on financial performance.

SAF's role in addressing GHG emissions and enabling future growth

The level of SAF production deployment required to control expected global aviation emissions growth is aggressive: ICAO forecasts that the commission of at least 170 new large SAF production facilities is required every year from 2020 to 2050, at an approximate capital cost of $15 billion to $60 billion per year.[20] Other research teams forecast that nearly 270 biorefineries will be required globally per year, costing between $21.9 and $87.6 billion annually, to produce 280 billion gallons per year.[21] For scale comparison, the estimated SAF investment is approximately one-fifth of current global petroleum-sector investments (upstream and downstream).[22]

Offsets via ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) system may provide a near-term opportunity to address emissions growth while SAF production becomes established. Two critiques of the CORSIA system (which are similar to critiques for the use of offsets in the transportation sector generally) are that while they incentivize emissions reductions in other sectors, they do not directly reduce emissions within the aviation sector (as offsets can be sourced from a range of project types). Secondly, as offsets will almost assuredly be a cheaper option in the short term, they will compete directly with SAF as a compliance option. SAF, on the other hand, provides a means to reduce sector GHG emissions within the aviation sector using existing fuel and engine configurations.

At present, there are seven SAF production pathways approved for commercial use. The pathways are listed in Table 1.

Table 1: American Society for Testing and Materials (ASTM) D7566 (Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons) approved SAF pathways*

Technology	Code	Feedstock	Max blend %	Status
Hydroprocessed Esters and Fatty Acids	HEFA	Renewable fat, oil and grease	50%	Commercially deployed
Fischer-Tropsch	FT	All biomass and household waste	50%	Approved under ASTM D7566, currently no technical barriers to widespread implementation. Commercial facilities starting production in 2020-2021.
FT Synthesized Paraffinic Kerosene plus Aromatics	SPK/A	All biomass and household waste	50%	Approved under ASTM D7566, currently no technical barriers to widespread implementation.
Alcohol to Jet	ATJ-SPK	Sugars, biomass, waste gases	50%	Approved under ASTM D7566, currently no technical barriers to widespread implementation.
Synthesized iso-paraffins	SIP	Sugars	10%	Approved under ASTM D7566, currently no technical barriers to widespread implementation.
Catalytic Hydrothermolysis Jet Fuel	CHJ	Renewable fat, oil and grease	50%	Approved under ASTM D7566, currently no technical barriers to widespread implementation.
Co-processing		Renewable fat, oil and grease	5% (refinery input)	Approved under ASTM D1655 rather than D7566, currently no technical barriers to widespread implementation.

20 International Civil Aviation Organization, *2019 Environmental Report: Aviation and Environment*.

21 Staples, et al., "Aviation C02 emissions reductions from the use of alternative jet fuels."

22 Ibid. The analysis estimates facilities with nameplate capacity of .22 MT, roughly 5000 BPD or 75 million gallons per year (p. 351). The analysis does not explicitly consider re-purposing existing refineries and focuses on facility capacity sizes that are lower than those currently established in the US Gulf Coast, the European Union (Finland, Italy, Netherlands, France), and Singapore. The authors note this on p. 352, "we note that bio-refinery capital costs could be lower than those assumed here, to the extent that existing refining or bio-refining capacity could be retrofit for production of AJF."

* "Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons," ASTM International, accessed April 2020, https://www.astm.org/Standards/D7566.htm.

SAF production, briefly

Companies pursuing SAF production have made significant progress in establishing a diverse set of technologies and feedstocks that each merit further recognition, but doing so is outside the scope of this report. These pathways, such as Alcohol to Jet (ATJ) and Fischer-Tropsch (FT), which can incorporate existing commercial feedstock sources and those from evolving technologies like industrial waste-gas utilization and direct air capture, among others, will further mature and establish market share.[23]

Among the approved pathways in Table 1, it is estimated that over 95 percent of SAF used in commercial flights has been produced through the Hydroprocessed Esters and Fatty Acids (HEFA) pathway.[24]

Major barriers to the expanded use of SAF

SAF's primary barriers are systemic and policy based. This is due in large part to balkanized policy efforts to decarbonize the transportation sector, which includes simultaneous but separate efforts (which vary across jurisdictions) to incentivize lower-carbon-footprint transportation fuels and to the substitution of renewable fuels for hydrocarbon fuels in certain parts of the transportation sector (like road transportation) but not others (like aviation fuels). None of the policy efforts take a consistent approach to aviation emissions. A policy approach that sought to reduce emissions across all transportation modes and fuel types would include SAF development, given that it is the primary means by which aviation can be decarbonized, unlike other segments of the transportation sector which have multiple options to address emissions.

There are concerns that increased SAF production would reduce the limited feedstock available for biodiesel and renewable diesel production—which, because they can be less energy intensive to produce, especially biodiesel, can have greater GHG emissions reductions in ground transportation than SAF does in aviation. However, a policy that aims for maximum emissions reduction across the entire transportation sector would focus on all aspects of fuel switching—including renewable fuels, electrification, hydrogen, and natural gas/biogas—for non-aviation segments of the sector while recognizing that the range of technologies available to ground-transportation are far less developed in aviation and are unlikely to reach commercial scale soon.

HYDROPROCESSSED ESTERS AND FATTY ACIDS (HEFA)

Based on its current level of use relative to other SAF pathways and its use under existing low carbon fuel programs, HEFA is described in greater detail:

HEFA SAF is produced from oleochemical feedstocks (such as plant oils, animal fats, and recycled products such as used cooking oil). These feedstocks react with hydrogen in a refinery-type environment to remove oxygen and separate the triglyceride into individual hydrocarbon chains. In a final processing step, the hydrocarbon chains are 'cracked' to produce a fuel that fits the target specifications. The HEFA process creates a mix of diesel, jet fuel, and naphtha and other light ends (that can be further processed into other energy products). The HEFA SAF production process is similar to that of Renewable Diesel (RD), but with additional distillation requirements. Renewable Diesel is a diesel substitute fuel that complies with ASTM D975. If a facility is designed to maximize HEFA SAF production, it is estimated that a maximum of 50 percent of the product yield would be SAF and in the target carbon chain length of eight to sixteen carbon atoms. HEFA SAF can be blended in up to 50 percent mixture with fossil jet fuel.*

* It is understood that there is preference among SAF users to incorporate blends with less than the maximum composition permitted by the ASTM standard. The rationale for blending at less than the 50% percent specification maximum is that SAF can be blended with fossil jet fuels with different aromatic contents and minimize any requirement for re-blending and re-certification.

23 Dr. Mark Staples, "Long-term CO_2 emissions reduction potential of aviation biofuels in the US," PowerPoint presentation, Washington, DC, December 5, 2018, http://www.caafi.org/resources/pdf/2.3_Future_Production.pdf; and Emily Newes, Jeongwoo Han, and Steve Peterson, "Potential Avenues for Significant Biofuels Penetration in the U.S. Aviation Market," National Renewable Energy Laboratory, April 2017, https://www.nrel.gov/docs/fy17osti/67482.pdf.

24 As a review of all SAF technologies is beyond this report's scope, see: Hitchcock, *Ready for takeoff?*

To enable SAF technology in a political context where whole-of-sector transportation policies seem out of reach, the following issues need to be overcome.

SAF has a higher production cost and market price compared with fossil jet

HEFA SAF is currently estimated to have a production-cost that is at least twice the price of pre-COVID-19 fossil jet fuel.[25]

At present, there is no visible market price for SAF that enables comparison with fossil jet fuel; however, industry estimates a price range of two to three times above fossil jet fuel. With few facilities that produce SAF on an ongoing basis, supply scarcity causes elevated market prices beyond SAF's production cost premium alone. A portion of the price premium would likely be addressed through efficiency improvements and economies of scale as SAF production expands. New conversion technologies and supply chains for low cost feedstocks (e.g., wood waste and municipal solid waste) would also reduce SAF costs.

SAF has a price premium to RD related to its production process

Just as petroleum-based jet and diesel fuels are both distillate fuels produced in the same refinery, the process that produces RD (see the HEFA call out box) is also capable of producing SAF. On a comparative basis, the same amount of feedstock produces moderately less SAF than RD while requiring more energy inputs. Facilities intending to produce SAF would do so by modifying their production process to produce higher quantities of SAF relative to RD. As specific information on each RD and SAF facility's cost of production is not publicly available, the central explanation for SAF's production cost premium over RD is that increasing the fraction of SAF from oleochemical feedstocks requires higher hydrogen inputs (to further 'crack' the molecules into the jet fuel range) and results in lower yields compared to RD. Producing SAF also creates greater amounts of lower value co-products (e.g., Naphtha). It is estimated that up to 25 percent of RD production is in the jet fuel specification range, though it requires further distillation to extract.[26] Increasing jet yield through modifying the RD production process can improve jet yield to 50 percent, though it requires up to 30 percent more hydrogen while reducing the overall liquid fuel yield of the process from 80 percent to 70 percent by mass.[27]

It is inferred that SAF prices are derived from RD prices with an added premium for incremental operating expense and yield loss. An additional source of the premium is the opportunity cost for foregone policy incentives that are available for RD and inaccessible for SAF.

SAF may not achieve as much GHG emissions reduction per dollar than biodiesel/renewable diesel

Policies that focus on lowering the carbon footprint of specific liquid fuels in the transportation sector, as opposed to policies that focus on lowering economy-wide emissions, give more GHG reduction credits to biodiesel and renewable diesel than SAF. If renewable fuels were the only option for lowering the carbon footprint of the entire transportation sector, stringent policies would produce the optimal emissions-reduction outcome by allocating renewable content to both aviation and ground transportation. But with fuel switching options for ground and maritime transportation more readily available, and with aviation largely excluded under current transportation-sector GHG policies, the current approach misses opportunities for overall emissions reductions.

When policies exclude aviation fuels, there is an opportunity cost for diverting renewable content from ground-based applications to aviation. The opportunity cost takes the form of forgone policy incentives. Forgone policy incentives primarily derive from RD's eligibility for compliance credits under regulations where there is not an equivalent level of access, or any access at all, for SAF. The US Renewable Fuel Standard (RFS) and CA-LCFS are two relevant policies where SAF has access through opt-in provisions, but not at equivalent levels with RD.[28] This ultimately means that producing SAF is not as economically valuable as producing RD. Specifically, the foregone policy incentives

25 The ICCT estimates a HEFA production cost of €0.88 per litre ($3.71 per gallon, based on 0.8970 USD/Euro exchange rate). The EIA's published US Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB for December 9 is $1.83/gallon, making ICCT's estimated production cost 2.03 times the EIA's jet fuel spot price. See: Nikita Pavlenko, Stephanie Searle, and Adam Christensen, "The cost of supporting alternative jet fuels in the European Union," International Council on Clean Transportation, March 2019, https://theicct.org/sites/default/files/publications/Alternative_jet_fuels_cost_EU_20190320.pdf; and "U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB," US Energy Information Administration, accessed April 2020, https://www.eia.gov/dnav/pet/hist/eer_epjk_pf4_rgc_dpgD.htm

26 Matthew Pearlson, Christoph Wollersheim, and James Hileman, "A techno-economic review of hydroprocessed renewable esters and fatty cids for jet fuel production," *Biofpr* 7:1 (2013), 89–96, https://onlinelibrary.wiley.com/doi/abs/10.1002/bbb.1378.

27 Matthew Noah Pearlson, "A techno-economic and environmental assessment of hydroprocessed renewable distillate fuels," thesis, Massachusetts Institute of Technology, 2011, http://dspace.mit.edu/handle/1721.1/65508; as cited in "CBSCI Reports," Canada's Biojet Supply Chain Initiative, accessed April 2020, https://cbsci.ca/reports/#2752b34881465597f. This analysis pertains to a specific technology which may not be the yield calculations in other HEFA technologies.

28 Oregon has a similar program to California's LCFS. Oregon's Clean Fuels Program began in 2016.

derive from Renewable Identification Number (RIN) compliance credits under the RFS, and a portion of the CA-LCFS credit value (which is available to SAF blended in California, but at a lower rate to CA-LCFS credit generation from RD). Also included in foregone policy incentives in California is the imputed value of RD being zero-rated under the AB 32 Cap-and-Trade program and therefore generating value within that system when blended with diesel. Aviation fuel is not covered by the AB 32 Cap-and-Trade program, so zero-rated aviation fuels do not have any compliance benefit.

SAF purchase is through direct contract and, therefore, it is not clear what proportion of SAF's higher market price, as compared to RD and fossil jet, is due to higher production costs or the policy-driven opportunity cost of forgone RD production. Existing RD producers have little financial incentive to start or increase SAF production.

SAF's GHG performance and CA-LCFS

GHG benefits of SAF are quantified through lifecycle analysis (LCA) modeling that calculates avoided emissions compared with fossil jet fuel.[29] The avoided GHG emissions fluctuate based on feedstocks used and the system boundaries of the LCA model, including whether indirect effects, such as indirect land use change (ILUC), are included for SAF or the reference fossil jet fuel.[30] ICAO has established an internationally agreed upon LCA methodology for calculating SAF-related, carbon-equivalent emissions under ICAO's CORSIA system and released twenty-six default LCA values for SAF production pathways, each with their specific GHG performance compared with fossil jet fuel.[31] Additional environmental co-benefits from SAF are documented, including lower air pollutant and criteria air contaminant emissions, reduced contrail formation, and reduced black carbon emissions compared to fossil jet fuel.[32] As SAF is a relatively recent renewable market entrant, it is feasible that additional environmental and climate benefits may be established and included in SAF's LCA performance.

As most LCA studies of SAF have been conducted in a research, rather than regulatory, context, the GHG performance results from California's Low Carbon Fuel Standard regulatory agency, the California Air Resources Board, are useful. CARB has approved facility-specific CI values for SAF produced in California.

When the CA-LCFS was updated in January 2019 to recognize SAF as an eligible fuel to generate compliance units, the net impact of its inclusion was helping reduce the opportunity cost difference between SAF and RD, even though the cost difference still exists.

The specific calculation within California's LCFS is relevant.

Table 2: Facility specific CI values for SAF in California's LCFS

Fuel Pathway	Producer	Feedstock	Process Energy	CI (gC02e/MJ
Alternative Jet Fuel (AJF)	AltAir Paramount, LLC (World Energy)	Canadian Rendered Animal Fat	Natural gas, grid electricity, and hydrogen	**25.08**
Alternative Jet Fuel (AJF)	AltAir Paramount, LLC (World Energy)	Australia Rendered Animal Fat		**42.91**
Alternative Jet Fuel (AJF)	AltAir Paramount, LLC (World Energy)	North America Rendered Animal Fat		**37.13**
			Average SAF CI	35

29 *Biofuels for Aviation Technology Brief*, International Renewable Energy Agency, January 2017, https://www.irena.org/documentdownloads/publications/irena_biofuels_for_aviation_2017.pdf.

30 The GHG reduction performance of SAF relative to fossil jet fuel is dependent on multiple variables, including the feedstocks used, SAF production technology utilized, and configuration of the SAF supply chain. The emission intensity of the fossil jet to which the SAF is being compared, and the system boundaries and emission allocation approaches that evaluate the two fuels also impacts the GHG performance.

31 MSW achieves a default CI of 13.9, an 84 percent reduction below the global fossil jet default value of 89. *CORSIA Supporting Document: CORSIA Eligible Fuels—Life Cycle Assessment Methodology,* International Civil Aviation Organization, June 2019, https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA%20Supporting%20Document_CORSIA%20Eligible%20Fuels_LCA%20Methodology.pdf.

32 Burkhardt, Bock, and Bier, Mitigating the contrail cirrus climate impact; Neste, "Neste MY Renewable Jet Fuel wins award"; and Airport Cooperative Research Program, *Alternative Jet Fuels Emissions*.

Ultra-Low Sulfur Diesel (ULSD) has a 2020 LCFS CI value of 92.92. California made a regulatory determination to accord conventional jet fuel a CI value of 89.37 (through 2022). Much of this difference in CI value is due to California's estimation of the added energy inputs for desulfurizing ULSD (which is not required for aviation jet fuel). The average CI for certified RD pathways is 32, and the recently approved CIs for SAF have an average of 35. Using these values, RD generates considerably more LCFS credits (92.92 – 32 = 61) than does SAF when using the conservative default values (89.37 – 35 = 54.37), which effectively increases the value of RD relative to SAF approximately 11 percent.

SAF is further hindered (compared with RD) under the LCFS through policy aspects that primarily relate to diesel being a state-regulated fuel type, while fossil jet fuel is not:

- Dissimilar treatment under California's Cap-and-Trade system which gives additional value (beyond the LCFS) to RD, as fossil diesel is included while aviation fuel is not.[33]

- Market diesel costs are increased via the ability to pass-through LCFS compliance costs which increases the attractiveness of placing renewable content into that market (as opposed to one that is not covered by the LCFS or Cap-and-Trade.)

The above combines with RD's already lower production cost to make RD more attractive than SAF from a producer's standpoint.

SAF's recognition in the US RFS policy

The RFS was first promulgated under the Energy Policy Act of 2005 and was later updated through the Energy Independence and Security Act of 2007.[34] The RFS is included in the Clean Air Act[35] (CAA), the comprehensive federal law that regulates air emissions from stationary and mobile sources. The RFS allows SAF to generate compliance units without aviation fuel generating compliance obligations, also referred to as the "opt-in" approach.

The US RFS permits SAF to generate D4, D5, and D7 RINs if it is produced by hydrotreating using eligible feedstocks (D4, D5) or produced from cellulosic material (D7). This approach assists to make SAF more competitive with renewable diesel and increases familiarity with SAF while not approaching a mandated use obligation.

The specific details of how RINs are created through SAF blending are important: when SAF is produced using the hydrotreating pathway (which is eligible for D4 RINs), it generates 1.6 RINs per gallon, not 1.7, due to the lower volumetric energy density of aviation fuel (it is slightly below the threshold heating value of 123,500 British thermal units (Btu)/gallon for 1.7 RINs).

Table 3: Highlight table of LCFS and US incentive eligibility

Incentive	RD Incentive Eligibility	SAF Incentive Eligibility
LCFS Credit Generation	**YES** (vs. diesel baseline)	**YES** (vs. jet baseline), resulting in less LCFS credits per equivalent fuel volume
Cap-and-Trade compliance cost on covered fossil fuels	**YES** (RD includes value of reducing Cap-and-Trade compliance cost for diesel fuel)	**NO** (fossil jet is not obligated under Cap-and-Trade due to federal pre-emption)
LCFS compliance cost on covered fossil fuels	**YES** (RD includes value of reducing LCFS compliance costs for diesel fuel)	**NO** (fossil jet is not obligated under LCFS due to federal pre-emption)
US RFS RIN generation	**YES** (RD generates 1.7 RINS per qualifying gallon)	**YES**, but not competitively (SAF generates 1.6 RINS per qualifying gallon)

33 Aviation fuel is not included in California's LCFS or Cap-and-Trade programs due to the federal pre-emption prohibiting states and localities from regulating aviation fuel and aircraft emissions. Such regulations are handled at the federal level by the Federal Aviation Administration, and by the EPA, per Section 231 of the federal Clean Air Act.

34 US Congress, House, *Energy Policy Act of 2005*, HR 6, 109th Cong., introduced in House on April 18, 2005, https://www.congress.gov/bill/109th-congress/house-bill/6; and US Congress, House, *Energy Independence and Security Act of 2007*, HR 6, 110th Cong., introduced in House on January 12, 2007, https://www.congress.gov/110/plaws/publ140/PLAW-110publ140.pdf.

35 1963 - Clean Air Act as amended in 1970, 1977, 1990 (42 USC 7401 et seq.)

Although a small difference, it makes SAF less competitive when combined with the cost of SAF versus RD.

Notwithstanding that SAF is less competitive than RD under these programs, the current LCFS and RFS approaches are a useful starting place upon which additional inducements for SAF production and use can be layered.

SAF's barriers can be addressed through a range of policy options

As SAF has emerged relatively quickly as compared to ground-based alternative fuels, SAF has generally been included as an 'add-on' to existing renewable fuels policies. The barriers identified in this section will not be overcome without specific measures. The characteristics of effective SAF-enabling policy reflect what would be considered desirable for any type of renewable fuel policy. To be effective, SAF-specific policies/programs should:

- Be stable over time by having a sufficient duration to reflect project development timelines.
- Be stackable with other incentives.
- Be technology-neutral to enable diverse production pathways and supply chains to develop.
- Link incentives with GHG emission reduction performance.
- Allow access to a compliance credit market to mediate prices between renewable fuels and fossil fuels by ascribing a compliance value.
- Recognize needs of pre-revenue companies through clear access to non-dilutive capital via grants and loans.
- Incorporate mechanisms to encourage significant advances in SAF production capacity expansion, further technology development, and drive efficiencies to provide sufficient supply to achieve decarbonization of the aviation sector.
- Ideally, be national in scope to allow innovation and project development where it can be accomplished most effectively, but in the absence of or as a complement to federal action, states should not hesitate to act.
- Be designed with bi-partisan support to reduce reversal risk.

Menu of Policy Options for Incentivizing SAF Production and Use

US CAPITOL BUILDING, WASHINGTON, DC. UNSPLASH/LOUIS VELAZQUEZ

This section presents a non-exhaustive range of policy instruments to advance SAF production and use in the United States. As there are multiple barriers to widespread SAF utilization, a range of policy instruments is proposed. The policy options are broadly categorized based on their area of impact and implementation approach. Policy options range from attracting capital, incenting SAF production and use, and establishing ongoing sector progress through research and development activities. The order does not correspond to relative importance of the presented options.

The menu of policy options is drawn from policies and programs with demonstrated effectiveness in propelling research and development activities, enabling capital investment, and creating renewable fuel and power production. The policy options are not mutually exclusive; they can be implemented independently or in conjunction with one another. Select options build upon one another and are presented as variations (for example, multiple Renewable Fuel Standard and Low Carbon Fuel Standard modifications are included).

Policy Option Category 1: Attract capital to expand SAF supply

OPTION 1: Loan guarantee programs

OPTION 2: Eligibility of SAF projects for master limited partnerships (MLPs)

OPTION 3: Accelerated depreciation/'bonus' depreciation

OPTION 4: Federal Business Investment Tax Credit (ITC) with SAF-specific mandate

OPTION 5: Performance-based tax credit akin to US Internal Revenue Code Section 45Q

Policy Option Category 2: Assist SAF facility operation through targeted incentives and tax relief

OPTION 6: Blending incentives: Blender's Tax Credit (BTC)

OPTION 7: Production incentives: Producer's Tax Credit (PTC)

OPTION 8: Excise tax relief for unblended (neat) SAF from the Airport and Airways Trust Fund's domestic commercial fuel tax and/or domestic general aviation jet fuel tax

OPTION 8A: Excise tax relief for blended (mixed) SAF from the Airport and Airways Trust Fund's domestic commercial fuel tax and/or domestic general aviation jet fuel tax

Policy Option Category 3: Recognize SAF environmental benefits

OPTION 9: Make SAF zero-rated under carbon taxation

OPTION 10: "Make SAF zero-rated under cap-and-trade systems as they develop

OPTION 11: SAF eligibility for programs that improve air quality

Policy Option Category 4: Create demand by further incorporating SAF into existing RFS policies

OPTION 12: Inclusion of jet fuel in an RFS

OPTION 12A: RFS Variation 1: supply incentive with SAF multiplier

OPTION 12B: RFS Variation 2: SAF carveout within D5 (advanced) category

Policy Option Category 5: Create demand by further incorporating SAF into existing LCFS-type regulations

OPTION 13: LCFS/Clean Fuel Standard

OPTION 13A: LCFS Variation 1: LCFS with ongoing SAF opt-in and updated credit generation baseline

OPTION 13B: LCFS Variation 2: LCFS with SAF eligibility for book-and-claim accounting when injected into pipeline (or airport fuel blending system) anywhere in the country

OPTION 13C: LCFS Variation 3: LCFS with SAF opt-in with a trigger threshold for aviation CI reduction schedule

Policy Option Category 6: Demonstrate government leadership through ongoing SAF purchase, research and demonstration activities, and a clear statement of policy direction

OPTION 14: Government commitment to SAF use, carbon neutral air travel

OPTION 15: Government directed research and development activities

OPTION 16: Policy statement to establish direction of travel

Each policy option is described in greater detail below:

Policy Option Category 1: Attract capital to expand SAF supply

This policy instrument category assists capital deployment and enhances competitiveness through non-dilutive capital to address technology, market, and policy risks. This menu of policy options is derived from structures that are proven effective to mobilize project finance to build and operate production capacity.

OPTION 1: LOAN GUARANTEE PROGRAM

Description: Improves access to debt finance by backstopping lender risk against default.

Example: US Department of Energy (DOE) Title XVII Loan Guarantee Program for Advanced Biofuels. Enabled under the American Recovery and Reinvestment Act of 2009 (via an amendment to Title XVII of the Energy Policy Act of 2005), which provided assistance for near-term commercial projects, including up to $500 million for advanced biofuel projects.[36]

Advantage: Useful to assist in financing diverse, innovative biorefinery projects. Serves to de-risk technologies that may be challenging to finance for first-of-kind commercial scale facilities.

Drawback: Statutory interpretation can impede program delivery. Program terms may not align with market structure (e.g., fuel sales via spot market versus long-term, fixed price offtake agreements).

SAF-specific implementation: Create a new specific loan guarantee envelope that is primarily focused on SAF production capacity development.

OPTION 2: ELIGIBILITY OF SAF PROJECTS FOR MLPS

Description: MLPs combine the benefits of a private partnership (where profits are subject to tax when distributed) with the market liquidity of publicly traded companies. The sectors for which this structure is available are limited. Biofuels and SAF are currently not eligible for MLP treatment.

Example: MLPs are primarily utilized in the energy industry, including for firms that own and operate fossil fuel pipelines. MLP financing has created over $500 billion worth of US oil and gas pipelines and coal-related infrastructure.[37]

Advantage: MLPs provide a permanent federal incentive, unlike tax credits which may expire. MLP distributions can be tax advantaged (as they are not taxed at both the corporate and individual shareholder levels).

Drawback: MLPs are limited in their applicability and involve added tax preparation burden.

SAF-specific implementation: Expand the definition of 'qualified sources' eligible for MLP treatment in the US Tax Code to include renewable energy production and infrastructure that would include SAF projects.

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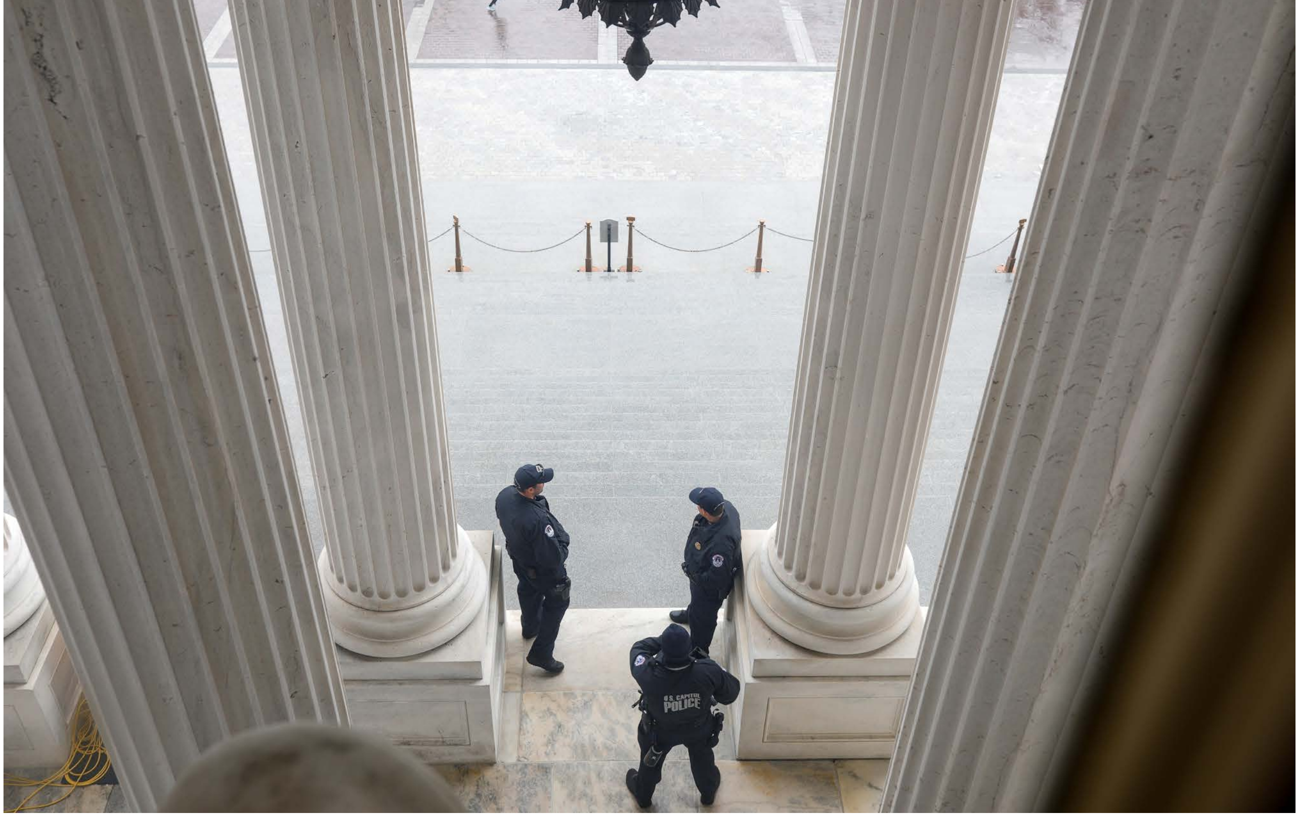
36 US Congress, House, *American Recovery and Reinvestment Act of 2009*, HR 1, 111th Cong., introduced on January 26, 2009, .

37 *Federal Policy Blueprint*, Carbon Capture Coalition, May 2019, https://carboncapturecoalition.org/wp-content/uploads/2019/06/BluePrint-Compressed-Updated.pdf.



US Capitol Police officers stand atop of the US Senate stairway, ahead of a vote on the coronavirus relief bill, on Capitol Hill, March 25, 2020. REUTERS/Tom Brenner

OPTION 3: ACCELERATED DEPRECIATION/‘BONUS’ DEPRECIATION

Description: Depreciation expense adjustments for specific asset classes can support large-scale capital deployment by reducing taxable earnings through depreciation expense claim in early years of operation. This helps attract private investment through offsetting income tax payable. This approach has enabled renewable power deployment.

Example: Five-year Modified Accelerated Cost Recovery System (MACRS), ‘bonus’ depreciation enacted under the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010, permits 50–100 percent of depreciation expense claim in first year of asset life.[38]

Advantage: Facilitates investment in specific sectors. Utilizes market forces by enabling private capital to select preferred projects within a targeted sector rather than positioning government to select recipients (pick winners).

Drawback: Premature implementation of start-dates and cut-off-dates may not match project development timelines and/or may penalize early movers and create competitive distortions.

SAF-specific implementation: Develop a specific MACRS depreciation schedule that applies to new SAF production, with a 100 percent bonus depreciation for assets placed into service before 2030. This strengthens the approach established for cost recovery from large-scale investments in solar, wind, and geothermal properties to reflect the scale of suggested buildout for SAF.

38 US Congress, House, *Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010*, HR 4853, 111th Cong., introduced on March 16, 2010, .

OPTION 4: FEDERAL BUSINESS ITC WITH SAF-SPECIFIC FOCUS

Description: The ITC tax credit allows deduction of construction and/or commissioning costs of a qualifying asset which can reduce income tax payable and flow through to investors. The ITC program notionally includes renewable fuel production though would have a new specific SAF focus to encourage investment.

Example: US Solar Investment Tax Credit enabled a 30 percent cost deduction from installing solar energy systems.[39]

Advantage: Directs sector investment through longer-term stability and accelerated payback. Can be simpler to implement compared to program funding where government selects recipient projects. Does not require government funding outlay and utilizes audited information collected by government revenue agencies.

Drawback: As with most tax credits, it can distort markets (early/late entrants) and increase sector risk if discontinued abruptly. May increase tax system complexity and reduce government revenue in the short term (offset by increased revenues in the long term).

SAF-specific implementation: Design a specific ITC program targeted at SAF production that uses the structure of previously implemented ITC programs for large wind facilities where the ITC schedule begins at 30 percent from 2020–2026, and declines annually to 24 percent in 2027, 18 percent in 2028, and 12 percent in 2029, and then expires fully at the end of 2034. As SAF projects will be higher capital cost than many other ITC renewable energy categories (wind, solar, hybrid solar lighting), the expiration date for the ITC should be based on when construction begins, rather than when the SAF facility is commissioned and fuel production commences.

OPTION 5: PERFORMANCE-BASED TAX CREDIT AKIN TO US INTERNAL REVENUE CODE SECTION 45Q

Description: Enabled under the Bipartisan Budget Act of 2018, the updated 45Q tax credit seeks to unlock investment capital to deploy carbon capture technology across industries such as electric power generation, natural gas processing, ethanol and fertilizer production, chemicals production, refining, the manufacture of steel and cement, and direct air capture. The 45Q credit is eligible for projects that begin construction prior to January 1, 2024 and can be claimed for up to twelve years after start-up. The credit amount varies based on project type, each with a credit ramp rate to achieve either a maximum of $35 or $50 per tonne. The tax credit is claimed by the owner of the capture equipment, though it can be contractually transferred to investors or project partners, thereby enabling different business structures to pursue this project type.

Example: A 45Q credit of $35/metric ton can be claimed by projects that geologically store C02 or C0 and use it in Enhanced Oil Recovery (EOR) or

39 US Tax Code Section 48 Energy Credit

OPTION 5 (CONTINUED)

convert into fuels, chemicals or other products. A 45Q credit amount of up to $50/metric ton can be claimed for C02 sequestration without EOR use.

Advantage: The benefit of the 45Q tax credit structure is its duration (twelve years). This tax credit type encourages investment in specific sectors and requires that the project activity (carbon sequestration and use) be accomplished (i.e., the facility must be in operation) before a credit value is generated. The program structure provides long-term policy stability that is required for high capital cost/long-lead time projects and is delivered via the US Tax Code rather than through program funding that must be reauthorized.

Drawback: Investment decisions based on updates to the tax code require clear and timely direction: Internal Revenue Service (IRS) guidance for implementing tax credits can be delayed, with the effect of introducing uncertainty and compressing project eligibility.

SAF-specific implementation: Explore the development of a specific 45Q-type program for SAF that is linked to the GHG reductions from SAF production. The desirable features of the program are its tax basis and duration. The credit level should be determined based on the avoided GHG emissions compared with fossil jet fuel using a standardized LCA approach whereby SAF with higher avoided emissions may receive an adjusted credit rate.

The credit duration can be similar to existing 45Q programs (twelve years) with a constant rate maintained so that competitive distortions are minimized between SAF production projects with different start dates. The difference between this credit type and the blending or production incentives in Category 2, below, is that the 45Q-type credit would be linked to the GHG reductions achieved rather than solely renewable fuel production.

Policy Option Category 2: Assist SAF facility operation through targeted incentives and tax relief

This category includes fiscal incentives to de-risk facility operation and improve cash flow through payments linked to production and/or blending. These incentives can assist with addressing the cost gap between SAF and fossil jet fuel as they are applied after a facility has been commissioned and can be linked with a specific quantity of fuel produced and placed into market. These incentives can be phased out as the sector becomes established and can access value from regulatory compliance credit markets.

OPTION 6: BLENDING INCENTIVES: BTC

Description: Tax credit that provides suitable incentive to produce and place renewable fuel into market, serving to decrease production costs compared with fossil fuel, and support investment in blending infrastructure. Tax credit is paid to the registered fuel blender and was extended on December 20, 2019 to cover the period from January 2018–December 2022.

Example: The Biodiesel and Renewable Diesel Blender Tax Credit provides a fuel tax credit for fuels containing biodiesel fuel (including renewable diesel) mixed with petroleum diesel that contains at least 0.1 percent diesel fuel. The tax credit is first assessed as a credit against the registered blender's fuel tax liability with any excess above this tax liability claimable as a direct payment from the IRS. It is noted that SAF qualifies as RD under the Biodiesel and Renewable Diesel Blender Tax Credit and receives the same incentive level, thereby improving economics relative to fossil jet fuel but not against RD.[40] In addition, the existing incentive only encompasses SAF derived from biomass, and so excludes SAF produced from DAC, MSW (non-biogenic portion), waste gases, etc.

Advantage: Useful to incent sector investment and ongoing fuel production and distribution from established facilities.

Drawback: Effectiveness is tied to duration and certainty of the incentive. May be dependent on continuous reauthorization. Uncertainty over extensions impacts facility profitability and impacts terms of fuel sale. If applied retroactively amid uncertainty, may not directly link with fuel production economics.

SAF-specific implementation: An incentive that is specifically targeted at SAF production and blending with fossil jet fuel can assist with overcoming the increased product cost and lower level of commercial deployment that is a current impediment to greater SAF penetration. If included with other renewable fuel blending incentives, the SAF credit value can be specified rather than defining SAF as RD. The tax credit should be established for the long-term (proposed as equivalent term to the 45Q-type program of twelve years) to encourage positive investment decisions. The blending incentive should be broad enough to include all SAF pathways (i.e., those listed in Table 1, and additional SAF pathways under development).

40 SAF is not specifically used in Section 40A of US Code re: biodiesel and renewable diesel used as fuel; it states, "fuel derived from biomass which meets the requirements of a Department of Defense specification for military jet fuel or an American Society of Testing and Materials specification for aviation turbine fuel."

OPTION 7: PRODUCTION INCENTIVES: PTC

Description: Tax credit that is paid to the fuel producer based on biofuel production (rather than blending).

Example: The Volumetric Ethanol Excise Tax Credit (VEETC) paid $0.51 to $0.45 per gallon from 2004–2011, including a Small Ethanol Producer Tax Credit of $0.10 per gallon.[41] The Second Generation Biofuel Producer Tax Credit (expired on December 31, 2017, and retroactively extended on December 20, 2019 through December 31, 2020) provides $1.01 per gallon of qualifying second generation biofuel produced and sold.[42] The State of New York's Department of Taxation and Finance implemented a Biofuel Production Credit of $0.15 per gallon of pure biodiesel (B100) or denatured ethanol produced; Kentucky has an income tax credit of $1.00 per gallon of corn or cellulosic ethanol that achieves ASTM specification D4806. Proposals were brought forward in previous sessions of Congress to transition the Biodiesel and Renewable Diesel Blender Tax Credit into a producer's tax credit.[43]

Advantage: Directly encourages renewable fuel production. Production tax credits would likely be limited to US production, thereby incentivising domestic investment with knock-on economic benefits. From a GHG perspective, the country of production will not have an impact as renewable fuels, like aviation and fossil fuels, are an increasingly global market.

Drawback: If dependent on continuous reauthorization, incentive will be perceived as uncertain, thereby not directly encouraging new facility construction. If the credit is limited to domestic production (which is likely with this credit type), international opportunities may be comparatively less appealing and the credit may be subject to trade dispute (e.g., anti-subsidy/anti-dumping actions).

SAF-specific implementation: Devise a stable, long-term (twelve year), SAF-focused PTC that directly incents producers (via decrease in federal income tax owing, additional amounts paid directly) to produce and enter SAF into commerce at a reduced cost premium over fossil jet fuel.

41 "Volumetric Ethanol Excise Tax Credit (VEETC)," US Department of Energy, accessed April 2020, https://afdc.energy.gov/laws/399.

42 Second generation biofuel is defined as liquid fuel that is (i) produced from any lignocellulosic or hemicellulosic matter that is available on a enewable or recurring basis or any cultivated algae, cyanobacteria, or lemna, and (ii) registered under section 211 of the Clean Air Act.

43 For example, see S. 944 and H.R. 2383, companion bills introduced during the 115th Congress entitled the American Renewable Fuel and Job Creation Act of 2017.

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OPTION 8: EXCISE TAX RELIEF FOR UNBLENDED (NEAT) SAF FROM THE AIRPORT AND AIRWAYS TRUST FUND'S DOMESTIC COMMERCIAL FUEL TAX

Description: This option goes beyond a tax credit by proposing the long-term or permanent relief from fuel excise tax established under the Airport and Airway Revenue Act of 1970, which established the Airport and Airways Trust Fund to provide a dedicated source of funding for the US aviation system. General aviation pays $0.218 (domestic general aviation jet fuel tax) per gallon of jet fuel in excise taxes to the Trust Fund, and Commercial aviation pays $0.043 (domestic commercial aviation fuel tax).[44] This fund supports the FAA and airport improvement programs, facilities and equipment, research, engineering and development, and airport operations. Jet fuel excise taxes, in total, provide approximately 4.1 percent of the tax revenue for the fund.

Example: Credits against fuel excise tax is an established strategy to incentivize the use of alternative fuels, which is contained in the BTC and PTC options above and in many state-level programs.

44 General aviation pays significantly more in the jet fuel excise tax than commercial aviation for the jet fuel tax as commercial aviation is subject to an array of additional taxes for use of the US aviation infrastructure system that are not applicable to general aviation. "Current Aviation Excise Tax Structure," Federal Aviation Administration, 2019, https://www.faa.gov/about/budget/aatf/media/Excise_Tax_Rate_Structure_2019.pdf.

OPTION 8 (CONTINUED)

Advantage: Excise tax relief can structurally reduce the price gap between SAF and fossil jet fuel by $0.218 per gallon, should an exemption under general aviation be considered, and $0.043, should an exemption under the domestic commercial aviation fuel tax be considered. The relatively minor contribution of fuel excise taxes to the fund revenue may make this exemption feasible.[45]

Drawback: The overall financial impact of this option will not be sufficient to fully offset SAF's current market price relative to fossil jet fuel; therefore, should be considered in concert with other policy options. Tax relief benefits will differ based on whether companies are operating or pre-revenue, and how the value is mediated along the supply chain by market participants.

SAF-specific implementation: Authorize a long-term, if not permanent, SAF exemption from the domestic general and/or domestic commercial aviation jet fuel tax to improve the economics of SAF production and insertion into domestic airports. The excise tax exemption can be reviewed after a specified duration. Additional implementation approaches can include offsetting forgone revenue from SAF volume excise tax relief by adjusting upwards the fossil jet excise tax levels. This adjustment could be determined annually as SAF volumes increase.

Option 8a: Excise tax relief for blended (mixed) SAF from the Airport and Airways Trust Fund's domestic commercial fuel tax and/or domestic general aviation jet fuel tax

SAF-specific implementation: This option is similar to the above, though it would apply to the entire fuel blend containing SAF and fossil jet fuel. This would further leverage the impact of an excise tax exemption structure by establishing a target SAF blend level at which the blended quantity of fuel would be tax exempt. For example, if a SAF blend threshold of 30 percent is established, the combined gallon (70 percent fossil jet with 30 percent SAF) would receive the exemption. This approach to fuel excise tax relief approach is similar to Illinois's exemption of the 6.25 percent fuel sales tax on biodiesel blends between 11 percent and 99 percent (B11-B99) and ethanol blends between 70 percent and 90 percent (E70-E90).[46]

45 For example, a 2 percent SAF use rate (roughly 400 million gallons) would be <0.1% of excise tax receipts.

46 "Biodiesel Laws and Incentives in Illinois," US Department of Energy, accessed April 2020, https://afdc.energy.gov/fuels/laws/BIOD?state=IL.

Policy Option Category 3: Recognize SAF environmental benefits

Includes fiscal mechanisms that price the carbon content of fuels to incentivize use efficiency and encourage fuel switching to less carbon intense options. This report does not advocate a carbon tax on fuels as an independently sufficient means to make SAF price competitive with fossil jet fuel; the price required would surpass politically acceptable levels and require design considerations yet to be successfully accomplished for transportation fuels. This option is presented as an option only if carbon taxation is proposed for application to jet fuel and other fuels.

This category also includes recognizing and valuing SAF's additional environmental benefits that occur from displacing fossil jet fuel. These benefits can be valued via improved LCA assessment or through access to specific funding programs which recognize these benefits (e.g., the Voluntary Airport Low Emissions program (VALE) and the Congestion Mitigation and Air Quality Improvement Program (CMAQ)).

OPTION 9: MAKE SAF ZERO-RATED UNDER CARBON TAXATION

Description: Referred to as a carbon tax, carbon price, or carbon levy. Works by setting a tax rate on carbon emissions for each fuel type, thereby providing a signal to reduce emissions. Differs from a cap and trade system by not stipulating an overall emission reduction target.

Example: There are current congressional proposals to implement carbon pricing.[47] Among these, H.R. 3966 proposes to exempt non-petroleum fuels from a $40/metric ton carbon tax which begins in 2022 and increases thereafter by 2.5 percent and adjusted for inflation.[48]

Advantage: Carbon taxation rates and coverage are conceptually simple and can be included in commercial decisions.

Drawback: Challenging to implement through public policy and often incorporate exemptions that increase complexity. Implementation approach may result in failing to advantage low-carbon fuels over fossil fuels. Exemption approach may obligate consumers to pay higher carbon tax rates than industrial emitters.

SAF-specific implementation: Should this type of broad carbon pricing policy be developed, ensure that it specifically exempts SAF from being assessed the full carbon tax rate to assist with bridging increased production cost. The tax exemption level could be tied to LCA performance of the fuel. Furthermore, if carbon taxation is implemented, carbon revenues could be directed towards SAF-supporting measures.

47 *Carbon Pricing Proposals in the 116th Congress*, Center for Climate and Energy Solutions, September 2019, https://www.c2es.org/document/carbon-pricing-proposals-in-the-116th-congress/.

48 US Congress, House, *Raise Wages, Cut Carbon Act of 2019*, HR 3966, 116th Cong., introduced in the House on July 25, 2019, https://www.congress.gov/116/bills/hr3966/BILLS-116hr3966ih.pdf.

OPTION 10: MAKE SAF ZERO-RATED UNDER CAP-AND-TRADE SYSTEMS AS THEY DEVELOP

Description: Cap-and-trade systems limit total GHG emissions by setting a maximum emissions level and allowing participants with lower emissions to sell surplus emission permits to larger emitters. This system creates supply and demand for emissions permits and establishes a market price for emissions and a value for avoided emissions.

Example: A federal cap and trade system does not exist. There are multiple state-level cap and trade systems: California's Cap-and-Trade Program (under AB 32); the Regional Greenhouse Gas Initiative (RGGI) that includes Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont; and the Western Climate Initiative (WCI), which administers a shared emission trading market between California and the Canadian provinces of Quebec and Nova Scotia.[49]

The European Emissions Trading Scheme (EU ETS) was launched in 2005 and is the largest international cap and trade system. Under the EU ETS, SAF is treated as having zero emissions and its use is exempted from the obligation to surrender CO_2 certificates.[50]

Advantage: Cap-and-trade systems utilize a market-based approach that can encourage innovation to reduce emissions and create tradable compliance units or allowances. This is in contrast to a taxation approach where the incentive exists to reduce taxation burden though those reductions are not tradeable among parties.

Drawback: Challenging to implement through public policy; often incorporate exemptions that increase program complexity. Systems may be limited to fixed emission sources. Any state cap-and-trade system would be pre-empted from covering aviation emissions.

SAF-specific implementation: Encourage SAF's recognition as an exempt low carbon fuel under the system to help bridge its cost gap with fossil jet fuel. Cap-and-trade systems alone will likely not incentivize SAF production and use. If implemented, revenues from auctioning allowances could be directed towards SAF supporting measures.

49 State policies are listed as examples; however, states are federally pre-empted from regulating aircraft emissions per section 231 of the Clean Air Act.

50 See: "Directive 2008/101/EC, amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community," European Parliament and the Council of the European Union, November 19, 2008, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0101.

This aerial picture shows the National Mall and the White House in Washington, D.C., June 8, 2017. REUTERS/Joshua Roberts

OPTION 11: SAF ELIGIBILITY FOR PROGRAMS THAT IMPROVE LOCAL AIR QUALITY

Description: SAF has environmental co-benefits including lower air pollution and criteria air contaminant emissions, reduced contrail cloudiness, and reduced black carbon emissions relative to fossil jet fuel that are not reflected in existing policies under which SAF has opt-in status.[51]

Advantage: While carbon dioxide emissions have the same impact regardless of where they are emitted, particulate matter and oxides of nitrogen can have differing climate forcing effects when released in the upper atmosphere and can have air quality impacts resulting from landing and takeoff (LTO). Ways to monetize the benefits of SAF's displacement of fossil jet fuel would recognize its performance beyond solely avoiding GHGs. These benefits would likely be SAF-specific, thereby helping address competitive issues between SAF and RD.

Drawback: Existing program rules do not recognize SAF as an eligible use of funds.

SAF-specific implementation: Modify eligibility under existing FAA grant pools such as VALE to allow for airports to value the air quality benefits of SAF use.

Explore additional means to monetize air quality benefits through allowing SAF to generate Clean Air Act Non-Attainment Area offsets.

51 Burkhardt, Bock, and Bier, *Mitigating the contrail cirrus climate impact*; Neste, "Neste MY Renewable Jet Fuel wins award"; Airport Cooperative Research Program, *Alternative Jet Fuels Emission*; and Dr. Jim Hileman, "Use of Sustainable Jet Fuels will Reduce Climate Impacts through both Reductions in CO_2 Emissions and Contrail Cloudiness," PowerPoint presentation, CAAFI Biennial General Meeting, Washington, DC, December 4, 2018, http://www.caafi.org/resources/pdf/3.2_SAJF_Benefits.pdf.

UNSPLASH/KEN YAM

Policy Option Category 4: Create demand by further incorporating SAF into existing renewable fuel policies (US RFS)

This category includes regulatory approaches that stipulate renewable fuel blending obligations (mandates) for fossil fuel suppliers. This is considered a supply incentive as the obligated party is the fuel refiner and supplier rather than the fuel user. However, the obligation to supply a specific fuel to the US market will necessarily create structural demand for that fuel by fuel suppliers. This approach has been utilized for decarbonizing ground transportation fuels via the inclusion of renewable fuel blending requirements (e.g., ethanol, biodiesel, RD). Concepts such as 'multipliers' are being incorporated as demonstrated by the European Union's Renewable Energy Directive (REDII), which includes aviation fuels on an opt-in basis.

The below discussion, which considers obligating (mandating) that renewable content be incorporated into jet fuel, is approached with sensitivity in recognition that policy-directed SAF inclusion proposals must be predicated on the realistic expectation that sufficient SAF will be available at a cost reflective of its production economics, rather than its current scarcity. Any policies directed at SAF blending and use should be preceded by measures to stimulate SAF production. This approach is similar to that of ground-based renewable fuels that have utilized federal and state incentives that date back to the Energy Tax Act of 1978, when ethanol blends above 10 percent were exempted from the $0.40 per gallon fuel excise tax, which was later changed into an income tax credit.[52]

This category contemplates potential changes to the US RFS that, in some cases, would fundamentally alter the dynamics of the program and therefore may not be immediately actionable in the current political environment surrounding the program. Nevertheless, the proposed options are presented here to encourage future policy design that incentivizes SAF production and use.

52 US Congress, House, *Energy Tax Act*, HR 5263, 95th Cong., introduced March 21, 1977, https://www.congress.gov/bill/95th-congress/house-bill/5263.

OPTION 12: INCLUSION OF JET FUEL IN A FEDERAL RFS OBLIGATION

Description: A renewable fuel use requirement is generally based on refined fossil fuel suppliers' volume of production or fuel sold into the market. Compliance can be achieved through blending renewable fuels, via the purchase and use of compliance units (e.g., RINs), or seeking firm-specific exemptions. The policy can specify fuel blending requirements per fuel type and may include environmental or sustainability criteria. RFS obligations can be based on volumetric quantity of fuel, energy-equivalent volumes (e.g., ethanol equivalent gallons), or energetic content of the fuel (e.g., EU RED and RED II determine compliance obligations based on fuel energy content).

Example: The RFS was first promulgated under the Energy Policy Act of 2005 and later updated through the Energy Independence and Security Act of 2007.[53] The RFS is included in the CAA,[54] the comprehensive federal law that regulates air emissions from stationary and mobile sources.

Advantage: When created and administered effectively, an RFS creates a durable market demand signal for renewable fuel production.

Drawback: The RFS policy structure may fail to create market certainty if statutory targets are not maintained by program administrators through granting waivers, exemptions, delays, and removing technical requirements of the program. Also, RFS policy in the US has been predicated on projected supply after significant policy support, which has not been in place for SAF.

SAF-specific implementation: The level of a volumetric blend requirement can be set to both reflect current SAF availability while providing a signal for investment in additional production capacity. As demonstrated by existing SAF and RD capacity (that can be directed towards additional SAF production), there are no barriers to supplying a modest mandate. The RFS approach is being considered in multiple jurisdictions (e.g., Sweden, Spain, France), with varying approaches (e.g., a 'negotiated mandate' in Spain), and implemented in others (Norway—as of January 1, 2020). The efficacy of a SAF mandate is yet to be determined with empirical data.

An RFS obligation on jet fuel is considered highly inappropriate by US airlines based on currently limited SAF availability, its price premium to fossil jet fuel, and legal limits on state and local regulation of aviation fuel. Incentives and voluntary SAF deployment initiatives are viewed by airlines as a realistic path towards greater SAF production and use. [55] The remainder of this category explores options for SAF participation in the US RFS.

53 US Congress, House, *Energy Policy Act of 2005*, HR 6, 109th Cong., introduced in the House on April 18, 2005, https://www.congress.gov/bill/109th-congress/house-bill/6; and *Energy Independence and Security Act of 2007*.

54 1963 - Clean Air Act as amended in 1970, 1977, 1990 (42 USC 7401 et seq.).

55 *Deployment of Sustainable Aviation Fuel in the United States: A Primer*, Airlines for America, August 2019, https://www.airlines.org/wp-content/uploads/2019/08/A4A-Sustainable-Fuel-Report_FINAL.pdf.

OPTION 12A: RFS VARIATION 1: SUPPLY INCENTIVE WITH SAF INCREASED RIN GENERATION RATES

Description: Expansion of the current RFS to provide SAF with a higher RIN generation rate and to address the current situation where SAF generates 1.6 RINS while RD generates 1.7.

Example: The recast REDII that comes into force on January 1, 2021 incorporates a 1.2 times multiplier for SAF that is produced from eligible feedstocks.[56] Similar to the RFS, fossil aviation fuel is not subject to the REDII requirements (though aviation emissions within the EU region are included in the EU's Emission Trading Scheme).[57]

Advantage: This approach builds on SAF's opt-in status by recognizing its benefits through a higher RIN generation rate. The approach seeks to address the existing inequities impacting SAF compared with renewable diesel as well as the higher price of SAF in relation to fossil jet.

Drawback: This approach may be opposed by existing renewable fuel producers based on the RIN codes for which SAF production is eligible. Multipliers may be supported by obligated parties if they are viewed as a means to decrease the overall volumetric obligation they face. As this approach does not place maximum limits on the use of the multiplier, it may reduce the demand for renewable alternatives to gasoline and diesel (if an excessive multiplier level is set).[58]

Multipliers create complexity when attempting to understand the physical volume of renewable fuels blended under regulation. Modifying RIN generation rates to advantage specific pathways may be criticized as departing from 'fuel neutrality' and allowing preferred outcomes (increased RINS per volume of SAF) to modify science-based approaches to RIN generation (where SAF's 1.6 RIN generation rate is based on a lower volumetric energy density).[59]

SAF-specific implementation: This approach will be utilized in the EU beginning in 2021 and would be structurally implementable in the US RFS.[60] It may require design and implementation acuity to alleviate concerns on demand erosion for established renewable fuel producers that access categories D4, D5, and D6. The inclusion of an increased RIN generation rate could be implemented with an overall increase in program ambition.

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56 "Renewable Energy – Recast to 2030 (RED II)," European Commission, last updated July 23, 2019, https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii.

57 Airlines are provided EU emission allowances based on fleet efficiency to mitigate the negative financial impact of the EU ETS inclusion. See: "Reducing emissions from aviation," European Commission, accessed April 2020, https://ec.europa.eu/clima/policies/transport/aviation_en.

58 The relatively low 1.2x multiplier level under RED II was set by the European Commission in order to not unnecessarily impact the market demand for other renewable fuels without access to the multiplier.

59 SAF's energy density is marginally below the 123,500 btu/gallon needed to get 1.7 RINS, but well above the threshold needed for 1.6 (approximately 116,000 btu/gallon). SAF has a higher energy density on a weight basis; for aviation, weight is typically a more important metric than volume.

60 Section 211(o)(5)(E) of the Clean Air Act grants the EPA broad discretion to allow for an "appropriate amount of credits" for "additional renewable fuel," which is defined as fuel that replaces fossil jet or home heating oil. The EPA would be within its discretion to provide a credit multiplier for Renewable Jet Fuel (SAF) under this provision. Further, there is precedent as RFS1 (Energy Policy Act of 2005) included 2.5x RINs for cellulosic or waste-derived ethanol.

OPTION 12B: RFS VARIATION 2: SAF CARVEOUT WITHIN D5 (ADVANCED) CATEGORY

Description: This option updates the above RFS modifications to include a specific SAF carveout within the Advanced Biofuel (D5) category which would be added to the existing D5 category of biomass-based diesel (D4), and thereby would put in place the RFS structure to require SAF-specific RINs to be used for compliance. SAF-specific RINS could be generated from any D5 fuel type, including cellulosic fuels (D3, D7) and would be indicated as applying to a SAF carveout through an 'A' suffix.

Advantage: This option would not change the Renewable Volume Obligations (RVO) calculation that is based on gasoline and diesel volume, so it does not create an obligation for fossil jet fuel. The impact would likely result in some amount of RD being used as SAF with limited compliance cost impact, as the total Advanced biofuel (D5) and Biomass Based Diesel (D4) volumes would remain unchanged.

Drawback: This variation is beyond the scope of what the US Environmental Protection Agency (EPA) can administratively alter in the RFS and would require congressional action.

SAF-specific implementation: A new SAF-specific category could be created, notionally called D5-A (for aviation), with a separate RIN requirement for obligated parties to the RFS. This option would not change the RVO calculation that is based on gasoline and diesel volumes. It would function to promote SAF production and use by providing the regulatory tool to require SAF inclusion in the RFS.

The D5-A nested level could begin modestly and be set following EPA analysis of domestic and global RD capacity and SAF production capability from all ASTM-approved pathways that may be available to supply SAF to the US aviation market. This option can be designed as volume-neutral, and not required to be paired with an overall increase in the D5 category.

Policy Option Category 5: Create demand by further incorporating SAF into existing LCFS-type regulations

This policy type includes LCFS, Clean Fuel Standards, and similar programs that require GHG carbon intensity reductions per unit of fuel. Lower carbon fuels are given a CI that determines their compliance value. LCFS policies contain credit trading markets and currently two states (California and Oregon) have adopted LCFS policies.[61]

OPTION 13: LCF/CLEAN FUEL STANDARD

Description: This policy type encourages the use of lower carbon fuels by obligating fossil fuel providers to gradually reduce the CI of fuels provided to the market. The CI values assessed for each fuel are compared to an annual declining CI benchmark. There are no LCFS obligations on jet fuel—state-level LCFS policies are pre-empted under federal aviation law from mandating the use of SAF, but similar to the federal RFS, SAF can be included on an opt-in basis.

Example: California's LCFS and Oregon's Clean Fuels Program are the leading US examples of this type of enacted policy. Similar policy initiatives are being considered in other US states.[62]

Advantage: LCFS-type regulations are considered to be technology-neutral by rewarding technologies that create the lowest cost emission reductions.

Drawback: Regulation complexity can dissipate department staff resources. Program can encourage obligated parties to preserve operating margins by directing compliance-driven investment into the fossil fuel supply chain emission reductions rather than renewable fuel purchase should program targets be insufficient to obligate use of a full range of compliance options.

SAF-specific implementation: The California LCFS and Oregon Clean Fuels Program were updated to allow SAF to participate on an opt-in basis beginning in January 2019.[63] In California, the California Air Resources Board (CARB) approved a temporary CI value for SAF of 50 gCO_2e/MJ (grams of $C0_2$ equivalent per megajoule of fuel), resulting in a 44 percent reduction from fossil jet fuel when it is produced from the feedstocks of 'fats/oils/grease residues,' i.e., used cooking oil. When SAF is produced from any feedstock derived from plant oils, CARB ascribed a temporary CI value of 70 gCO_2e/MJ, a 22 percent reduction from fossil jet fuel).[64] These CI values were considered conservative and are higher than the three approved Tier 2 pathways for World Energy of 25.08, 37.13, and 42.91, based on the source of the animal and poultry fat used to produce SAF.

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61 Oregon's policy is the Clean Fuels Program implemented by Oregon's Department of Environmental Quality. See: "Oregon Clean Fuels Program," Government of Oregon, accessed April 2020, https://www.oregon.gov/deq/aq/programs/Pages/Clean-Fuels.aspx

62 This includes, but is not limited to, the proposed Northeast and Mid-Atlantic Low Carbon Fuel Standard. This option does not preclude the federal consideration of an LCFS program. See: "Regional Low Carbon Fuel Standard Program: An Overview of the Northeast and Mid-Atlantic States Initiative," NESCAUM, January 6, 2010, https://www.nescaum.org/documents/lcfs-factsheet.pdf/.

63 The regulations use Alternative Jet Fuel (AJF) rather than the Sustainable Aviation Fuel term.

64 This value excludes palm oil and palm derivatives, as a sole feedstock or blended with other feedstocks. Low Carbon Fuel Standard Proposed new Temporary Fuel Pathway: Alternative Jet Fuel," California Air Resources Board, July 31, 2019, https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/comments/ajf_temp.pdf.

OPTION 13A: LCFS VARIATION 1: LCFS WITH ONGOING SAF OPT-IN AND UPDATED CREDIT GENERATION BASELINE

Description: The LCFS policy is augmented by allowing SAF to generate LCFS credits on an opt-in basis (without fossil aviation fuel generating debits), where the credit amount is based on a CI value for fossil aviation fuel that is at least equal to the CI value for ultra-low sulfur diesel (ULSD). In the 2019 California LCFS update, the credit calculation is based on a declining CI schedule for fossil jet fuel and credit creation is based on fuel insertion into in-state airports and therefore is not limited to intra-California or domestic flights. While the LCFS allows SAF credit generation, it is still not as competitive as RD—the aviation fuel baseline that determines the amount of LCFS credit per MJ of fuel is established below fossil diesel until 2023, at which point it becomes equivalent to the CI for diesel.

Example: California's LCFS now allows SAF to generate compliance credits without debits against a declining fossil jet baseline that is below the diesel baseline.

Advantage: This approach achieves support by helping address, though not eliminate, a production cost gap between SAF and renewable diesel while not obligating SAF use by airlines or its provision by fossil fuel suppliers in California.

Drawback: The LCFS credit creation calculation for SAF remains lower than renewable diesel, as the fossil jet CI value is below diesel until 2023, at which point the CI values become equivalent.

SAF-specific implementation: SAF is being enabled under the LCFS, therefore the SAF-specific implementation is to maintain and enhance this policy structure. As of January 2019, California's LCFS allows SAF introduced in California airports to generate LCFS credits without jet fuel generating LCFS obligations. With LCFS credit prices above $200/tonne, SAF has a compliance value that directly reduces the price gap with fossil jet fuel though still maintains a compliance price that is higher than that of renewable diesel, which gets more compliance credits per unit of fuel due to ULSD's higher CI value compared with jet fuel (92.92 gC02e vs. 89.37 gC02e).

An implementation option is to modify the fossil jet CI value. If the fossil jet CI value was set above the level for diesel, it would incentivize greater SAF production and blending. Such an approach could begin in 2023 and would serve to offset SAF's treatment in the LCFS regulation.[65] This approach could include a specific level of additional CI points to be added to the fossil jet baseline that reflect factors currently not included in the LCA value, such as contrail impacts, black carbon emissions, and SAF's zero sulphur content, which makes a comparison to ultra-low sulphur jet fuel, a product with an increased CI score, a more fitting comparison. Conversely, though with the similar net impact, this option also includes the potential for justifying lower SAF CI values based on non-GHG climate benefits (e.g., reduced contrail formation, black carbon impacts) that are particular benefits related to SAF's displacement of fossil jet fuel.

65 This approach was suggested during the California's LCFS re-adoption consultation by a group of airlines and SAF producers.

OPTION 13B: LCFS VARIATION 2: LCFS WITH SAF ELIGIBILITY FOR BOOK-AND-CLAIM ACCOUNTING WHEN INJECTED INTO PIPELINE (OR AIRPORT FUEL BLENDING SYSTEM) ANYWHERE IN THE COUNTRY

Description: This option increases the location flexibility of SAF use by allowing other airlines or airports to purchase and use SAF outside of California while still being able to access the value of the LCFS credit via a book-and-claim traceability system.

The use of book-and-claim accounting for emission reductions has precedent in California's program:

- Renewable Natural Gas that is pipeline injected outside of California is eligible to opt-in and generate LCFS credits using a book-and-claim system once it is compressed or liquified and dispensed to appropriate vehicles in California.[66]
- CCUS projects that are linked with oil and gas and renewable fuels (e.g., ethanol) can be based anywhere in the world and allocated via book-and-claim to generate LCFS credits provided the company sells transportation fuel into California's market (to which they would allocate the GHG reductions from CCUS).[67]

Advantage: Will allow SAF use outside of California to proceed at a faster pace than it would if it was dependent on other states developing similarly structured programs.

Drawback: Potentially reduces demand for in-state low CI fuel use and complicates GHG accounting for achieving emission targets if reductions occur outside of California.

SAF-specific implementation: Permit the use of book-and-claim to enable SAF to generate LCFS credits when inserted into the aviation fuel supply in locations outside of California's LCFS jurisdiction. Program design can ensure that emission reductions are not double-counted.

66 "Low Carbon Fuel Standard (LCFS) Guidance 19-05," California Air Resources Board, revised October 2019, https://ww3.arb.ca.gov/fuels/lcfs/guidance/lcfsguidance_19-05.pdf.

67 Direct Air Capture projects can be based anywhere in the world and do not require that fuels derived from captured C02 be sold in California. Alex Townsend and Ian Havercroft, *The LCFS and CCS Protocol: An Overview for Policymakers and Project Developers*, Global CCS Institute, 2019, https://www.globalccsinstitute.com/wp-content/uploads/2019/05/LCFS-and-CCS-Protocol_digital_version.pdf.

OPTION 13C: LCFS VARIATION 3: LCGS WITH SAF OPT-IN WITH A TRIGGER THRESHOLD FOR BINDING AVIATION CI REDUCTION SCHEDULE

Description: This updates the option 13a to include a trigger threshold for an aviation CI reduction requirement linked to a defined metric that establishes its feasibility. This option relies on the assumption that 'technology-forcing' regulations such as the LCFS can be nimble enough to respond to a new fuel's development progress by setting CI reductions that reflect the fuel's current commercial availability and scale-up potential. The trigger threshold should be determined through focused consultations with the aviation supply chain and seek to balance market certainty required by SAF project developers and fuel availability concerns by obligated parties and end users.

Advantage: If implemented effectively, this approach would provide market certainty for SAF project developers while avoiding the obligation for fuels to be used before the are available. The approach would address 'chicken or egg' (causality dilemma) issues.

Drawback: Defining mutually agreeable trigger thresholds and determining when they have been satisfied may be elusive. Should trigger thresholds fail to incent project development, they may forestall further efforts to create SAF supply and demand.

SAF-specific implementation: Potential trigger thresholds may include:

1) An established quantity of SAF that has been placed into market in the regulated jurisdiction.

2) The generation of a specified amount of LCFS or CFS credits from SAF blending.

3) A minimum amount of in-jurisdiction SAF production.

4) A minimum amount of domestic or global SAF production.

5) A minimum amount of RD capacity with distillation capability in recognition that RD producers can make SAF.

6) A specified amount of time once the intention to establish an aviation CI has been officially communicated.

Policy Option Category 6: Demonstrate government leadership through ongoing SAF purchase and use, sector advancement through directed research, development, and demonstration activities, and motivate SAF strategic focus via statement of policy direction

This broad category includes SAF use commitments by government, activities that support future sector advancement through directed research, development and demonstration activities to remove technical barriers to SAF production and use, and activities that propel SAF project development interest through government communication of intended policy direction. While statements of policy direction are not a substitute for concrete energy policy, they can direct public focus and motivate commercial interest in advance of specific policy inception.

OPTION 14: GOVERNMENT COMMITMENT TO SAF USE, CARBON NEUTRAL AIR TRAVEL

Description: Federal, state, local governments, and the US military can commit to renewable fuel/SAF procurement to reduce environmental impacts of air travel and operations while assisting sector development through long-term contractual purchase.

Example: Alternative fuel (especially ethanol and biodiesel) adoption has advanced through federal and state government fleet purchase requirements and commitments such as sections 303(b) and 507(o) of the Energy Policy Act of 1992, as amended (requiring federal and state government fleets to acquire 75 percent of their annual light-duty vehicle acquisitions as alternative fuel vehicles (AFVs)), and sections 400AA(a)(3)(E) (requiring federal AFVs capable of operating on alternative fuel and on gasoline (or diesel) to be operated on the appropriate alternative fuel) and 400FF(a) of the Energy Policy and Conservation Act, as amended (requiring federal agencies to increase their fleets' annual alternative fuel consumption by 10 percent each year).[68] Additionally, the US Navy's Great Green Fleet initiative demonstrated the effectiveness of renewable diesel use (in 50 percent mixture) in military applications.

Advantage: Creates stable demand and useful product demonstration experience. Useful prior to adoption of purchase commitment to establish functionality and useful post adoption to provide consistent demand and demonstrate successful implementation as a visible example for other organizations.

Drawback: Programs may be discontinued or modified in response to political processes. Initial fuel purchases may be at higher cost than existing fossil fuels that can invite criticism. Government agencies may be prevented from entering into purchase contracts with sufficient duration to support project development.

SAF-specific implementation: All purchases of SAF to date are driven by voluntary commitment rather than regulatory obligation, making this policy option fundamental for increasing product demand under current conditions. Purchase requirements or commitments by government agencies can directly lead to new facility construction and operation (as the US Navy's initiative was successful in accomplishing). Although voluntary commitments will be

68 Codified in 42 U.S.C. §§ 13212, 13257(o), 6374, and 6374e; see also Executive Orders 12261, 13149, and 13423 (no longer in effect).

OPTION 14 (CONTINUED)

limited, they can increase installed SAF capacity and allow producers to learn from operational experience.

Further, US military fuel purchasing can be on a longer-term basis that can provide demand stability for SAF producers. For example, the White House Military Office could commit to operating Air Force One on SAF whenever practicable, and the US Department of Defense could make a similar commitment for select military aircraft types.

OPTION 15: GOVERNMENT DIRECTED RESEARCH AND DEVELOPMENT ACTIVITIES

Description: This includes government research and directed funding to address barriers to SAF production and use, often with defined target feedstock types and conversion processes.

Example: DOE's Bioenergy Technologies Office (BETO), administered by the Office of Energy Efficiency and Renewable Energy (EERE), focuses on "early-stage research and development for biobased fuels, products, and chemicals that can maximize the use of abundant US biomass resources, including cellulosic biomass, algae, and wastes, to advance US economic competitiveness in global energy markets and enhance US energy security."[69] Additional examples include:

The FAA Centre of Excellence for Alternative Jet Fuels and Environment (ASCENT), established in 2013, is co-led by Washington State University and the Massachusetts Institute of Technology (MIT) to pursue solutions to energy and environmental challenges in the aviation sector.

The Continuous Lower Energy, Emissions and Noise (CLEEN) program was established to reduce aircraft fuel burn emissions and noise through technology and advanced alternative jet fuels. The FAA launched CLEEN I in 2010 (federal investment of $100M) and it is currently in a second phase CLEEN II (federal investment of $100M) which runs from 2015 through 2020.[70]

Advantage: Programs like BETO, CLEEN, and ASCENT can direct substantial government resources and research focus towards specific areas to enable future SAF production from pre-commercial feedstocks using novel conversion technologies. This program type can reduce technology risk and leverage industry investment for greater impacts.

Drawback: Focus areas may be determined by political priority. Program funding areas may be extremely broad, potentially preventing substantial progress within a specific sector. Program funding may be focused on innovation rather than de-risking technologies to enable capital deployment.

SAF-specific implementation: BETO, CLEEN, ASCENT, and other programs have provided significant funding for SAF feedstock and technology development. Enhanced annual funding for these programs and even greater prioritization of SAF-related issues, including the funding of ASTM certification activities to progress additional SAF production pathways, can increase the scale of technical advancements leading to faster and more significant SAF research progress.

69 "An Historical Time for Renewable Jet Fuel," US Department of Energy Office of Energy Efficiency & Renewable Energy, November 26, 2018, https://www.energy.gov/eere/articles/historical-time-renewable-jet-fuel.

70 "Fact Sheet – Continuous Lower Energy, Emissions, and Noise (CLEEN) Program," Federal Aviation Administration, March 4, 2020, https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22534.

OPTION 16: POLICY MAKER STATEMENT TO ESTABLISH DIRECTION OF TRAVEL

Description: Setting aspirational goals of specific production or use amounts to signal future intent to develop comprehensive SAF policy measures. Can be linked to implementation of future policies, sending a signal for project planning.

Example: The 2007 State of the Union speech established executive branch ambition to expand the use of renewable fuels prior to the enactment of enabling legislation (RFS blend targets of 36 billion gallons were established under the Energy Independence and Security Act of 2007 which following the State of the Union).[71]

For SAF specifically, in 2007 FAA Administrator Michael Huerta announced the goal of 1 billion gallons of production by 2018.[72]

Advantage: Communicates direction of travel; signals an impending policy focus.

Drawback: Statutory follow-through may differ from stated targets in scope and regulatory design. Capital-intensive sectors will require greater policy definition prior to making investment decisions.

SAF-specific implementation: A statement by a US legislator or senior civil servant of commitment to specific SAF production and use targets with indication of type and magnitude of enabling measures.

71 US Congress, House, Energy Independence and Security Act Of 2007.

72 Michael Huerta, "Partnership for Production," speech, Commercial Aviation Alternative Fuels Initiative (CAAFI) General Meeting and Expo, Washington, DC, January 28, 2014, https://www.faa.gov/news/speeches/news_story.cfm?newsId=15654.

Conclusion: Creating a Pragmatic Way Forward

UNSPLASH/SAMUEL'S PHOTOS

This report proposes the following immediate and near-term efforts that incorporate the policy options reviewed in Section 4:

Immediate Efforts (2020–2021) to Reduce the Incentive Gap between SAF and RD

Pursuing these immediate efforts is predicated on the argument that, in the absence of transportation-sector-wide decarbonization policies that include aviation fuels, aviation merits specific policies to support decarbonization as it does not yet have and seems unlikely to have in the future the same fuel-switching options as other portions of the transportation sector. Steps that can be pursued promptly are those that modify existing regulations (that already allow SAF to opt-in) so that SAF nears competitiveness with RD. These options are contained in policy categories 4 and 5 that create demand by further incorporating SAF into the US RFS and the California LCFS.

The included options would improve current SAF enabling regulations (LCFS, RFS) and modify excise tax treatment:

1. Renewable Fuel Standard:

- Modify the US Renewable Fuel Standard (RFS) to equalize the renewable Identification Number (RIN) generation rates between SAF and RD so that both fuel types produce 1.7 RINS using Option 12a (**Supply Incentive with SAF increased RIN generation rates**).

- Create a SAF-specific inclusion within the RFS's Advanced Biofuel category using Option 12b (**SAF carveout within D5 (advanced) category**).

2. Low Carbon Fuel Standard:

- Update the credit generation baseline for SAF through implementing Option 13a (**Low Carbon Fuel Standard with ongoing SAF opt-in and updated credit generation baseline**).

- Allow the use of book-and-claim accounting for recognizing SAF use outside of California via Option 13b (**Low Carbon Fuel Standard with SAF eligibility for book-and-claim accounting when injected into pipeline (or airport fuel blending system) anywhere in the country**).

3. Blender's Tax Credit:

- Establish an enhanced SAF-specific credit to target SAF production and blending with fossil jet fuel via Option 6 (**Blending Incentives: BTC**).

4. Excise Tax Exemption:

- Provide an excise tax exemption reduce the current price gap with fossil jet fuel through Option 8

(**SAF (Neat) Excise tax relief from the Airport and Airways Trust Fund's domestic commercial fuel tax**).[73]

Near-Term Actions (2020–2025) to Attract Capital to Establish New SAF Production Capacity

Concurrent with and following the immediate actions to address the incentive gap, efforts can be directed towards establishing new SAF production through attracting investment capital and providing a firm market demand signal.

1. Review SAF production economics and consider additional targeted incentives as included in Policy Category 2 (**Assist SAF facility operation through targeted incentives and tax relief**) and Policy Category 3 (**Recognize SAF environmental benefits**), specially including Option 6 (**Blending Incentives: BTC**).

2. Select and implement options included in Policy Category 1 (**Attract capital to expand SAF supply**) that are the most feasible in the current political and regulatory context.

3. As additional SAF production capacity moves towards investment decisions, create secure demand through government commitment to fuel use as contained in Policy Category 6, Option 14 (**Government commitment to SAF use, carbon neutral air travel**) to encourage project development.

4. As additional SAF production capacity progresses towards commissioning and start-up, create further secure demand through updating renewable/ low carbon fuel regulations (Policy Categories 4 and 5) or new policies that achieve the same durability of demand signal.

5. Spur sector development with indicative federal statement of intended SAF activity as included in Policy Option Category 6, Option 16 (**Policy Maker Statement to Establish Direction of Travel**).

Regardless of which specific policy options are put forward, SAF policy should be crafted with the following guidelines in mind:

1. **Specific SAF policy is merited.** SAF will not be enabled through broad, generic renewable fuel production incentives alone. It needs specific, targeted policies that can address the unique circumstances of its production and use.

2. **Existing barriers should be swiftly removed.** Policy efforts must first seek to reduce disincentives to produce SAF (relative to other renewable fuels) in existing regulations and signal intent for increased SAF production through new program and tax policy design.

3. **Policy options that lead towards obligated SAF usage will have a higher likelihood of success when paired with program design and fiscal measures to help reduce the cost gap between SAF and fossil jet fuel.** It is not surprising that the commercial aviation sector does not currently support SAF use requirements or blending obligations when the current deployment status is limited and there is a two-to-three times price differential vs. fossil jet. Should effective SAF production policy be in place that can lead to greater fuel availability and lessened price premiums, the aviation industry would be reasonably expected to support mandates that help expand SAF supply and sector development that help achieve their self-imposed substantial greenhouse gas (GHG) reduction ambitions.

4. **Reducing SAF's price premium vs. jet fuel is important, but eliminating it is not a prerequisite to proceeding with SAF policy.** Narrowing the price gap will help incremental voluntary use though pursuing price parity should not dominate policy approaches to stimulating SAF use. This recognizes that SAF, while fully fungible with fossil jet fuel, is not the same product.

5. **Policy options should be informed by results of other jurisdictions.** Regulatory design efforts should be informed by periodic assessments of available supply and performance of other fuel use regulations (e.g., Norway's existing SAF blend requirement).[74]

73 The recently passed CARES Act (S.3548) exempted commercial aviation from all (kerosene) jet fuel excise taxes for the remainder of 2020.

74 "Aviation will use 0.5 percent advanced biofuel from 2020," Norwegian Ministry of Climate and Environment, October 4, 2018, https://www.regjeringen.no/no/aktuelt/biodrivstoff-i-luftfarten/id2613122/.

About the Author

Fred Ghatala is a partner of Waterfall Group, an advisory focused on advanced biofuels and bioenergy based in Vancouver, British Columbia. Specific to the aviation sector, he has led three different projects focused on moving Sustainable Aviation Fuel (SAF) forward in Canada: Canada's Biojet Supply Chain Initiative, which integrated SAF into the shared hydrant fuel system at Toronto's Pearson International Airport; the Civil Aviation Alternate Fuel Contrail Emission Research project, which tested the impact of high SAF blends on contrail formation; and BioPortYVR, a feasibility study for ongoing SAF use in Vancouver's International Airport. Fred served as head of Canadian delegation to ISO 13065 'Sustainability Criteria for Bioenergy,' an international standard published in 2015, and is the director of carbon & sustainability for Advanced Biofuels Canada (ABFC), a national industry association established to advance the production and use of advanced biofuels in Canada. Fred leads ABFC's work to establish biofuel carbon value, lifecycle analyses in regulations, and sector engagement in sustainability initiatives. Prior to this, Fred was director of government affairs for Canadian Bioenergy Corporation, which developed a co-venture with Archer Daniels Midland to construct Canada's largest biodiesel facility, which commissioned in 2013. Fred has worked for the Aga Khan Foundation (Washington, DC) to coordinate international development projects in Asia and with PricewaterhouseCoopers (Mexico City) to assess environment management systems in Mexico's petroleum sector. Fred received a bachelor's degree in finance from the George Washington University (magna cum laude) and a Master of Science from the University of British Columbia, where his research focused on carbon policy and the Clean Development Mechanism.

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