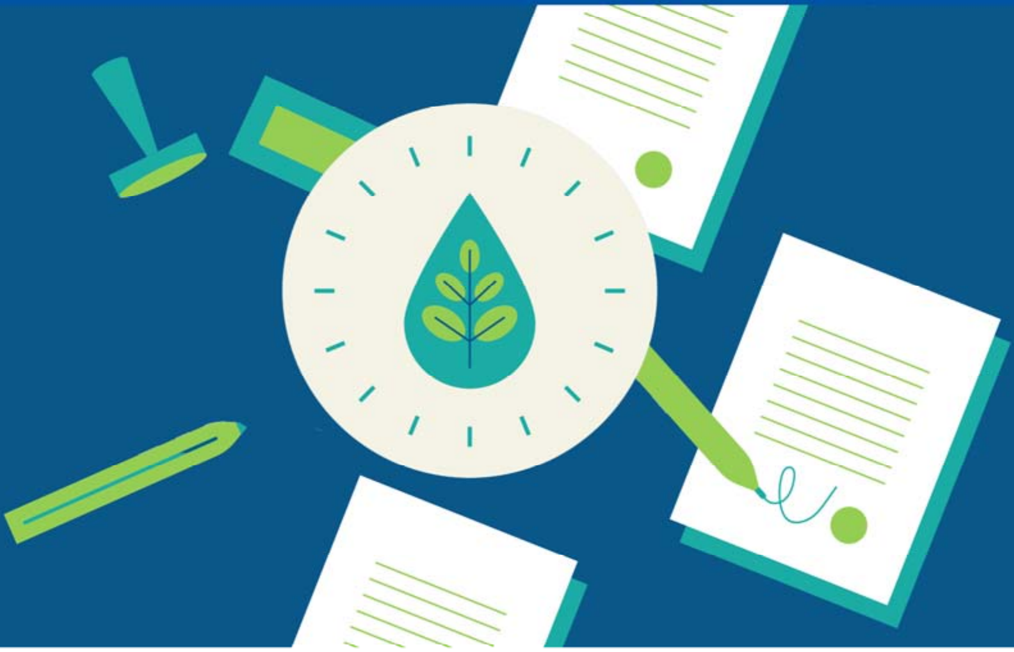
INTERNATIONAL CIVIL AVIATION ORGANIZATION

GUIDANCE ON POTENTIAL POLICIES AND COORDINATED APPROACHES FOR THE DEPLOYMENT OF SUSTAINABLE AVIATION FUELS



ICAO COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION

JUNE 2022

Guidance on potential policies and coordinated approaches for the deployment of SAF

This guidance has been developed by the ICAO Committee on Aviation Environmental Protection (CAEP) based on various studies developed since 2016. Based on these developments, it summarizes potential policies and coordinated approaches for the deployment of SAF. It completes a toolbox of guidance material for use by ICAO Member States and can be used in combination with the ICAO SAF Rules of Thumb, a set of heuristics that can be utilized to make order-of-magnitude estimations related to SAF costs, investment needs and production potential that could inform policymakers and project developers.

GUIDANCE ON POTENTIAL POLICIES AND COORDINATED APPROACHES FOR THE DEPLOYMENT OF SUSTAINABLE AVIATION FUELS

TABLE OF CONTENTS

---

1. Introduction

Sustainable aviation fuel (SAF) is being pursued globally as an element of a comprehensive basket of measures to address aviation's impact on climate change and the environment. Use of SAF by the world's aviation industry has the potential to provide significant life-cycle reductions in aviation greenhouse gas emissions as well as reductions in conventional air quality pollutant emissions. SAF are hydrocarbon jet fuels that are fully fungible with existing conventional kerosene and can be 'dropped in' to existing fueling infrastructure and aircraft jet engines without any modification. A diverse group of SAFs have been approved as safe for use by the aviation community and a comprehensive evaluation process is in place for additional candidate fuels that are actively seeking approval. For more general information on SAF please see ICAO's SAF website.

While SAF have been confirmed to be technically feasible, broadening the availability and cost effective production of SAF remains a significant challenge. As of the writing of this document, SAF production capacity is limited by a number of barriers including significantly higher costs of production for SAF in comparison to conventional kerosene; limited feedstock and fuel production infrastructure; and, perceived high risks and costs to finance SAF infrastructure. As long as these barriers exist, a policy intervention will be required to develop SAF production beyond small scale.

In general, a supporting policy framework is in place in those states where SAF production has initiated. For the build out of a sustained global SAF production industry, though, additional supporting policies will be necessary. Due to different climates, agricultural systems, resources, and economic factors, the opportunities for SAF production may be unique in each specific State. The political barriers, existing regulatory structure and economics are also likely to be unique in each State. As such, there is not a single path to successful SAF policy implementation. Rather, a considered and customized strategy can be effective.

This policy guidance document is intended as a support reference for ICAO Member States seeking to develop SAF production or part of the SAF supply chain such as feedstock production. It is provided as an introduction and primer on the types of policy mechanisms and their impacts. It provides examples of SAF policy approaches being utilized and considered around the world. It also provides links to additional resources that may be useful. It is a resource for use in consideration of what potential policy instruments could play a role in addressing barriers and incentivizing SAF production in an interested State.

Over the course of the period of development of this document (2020-2021), a dramatic acceleration in SAF policy activity occurred in both States and public/private coalitions. This document attempts to capture the current status on SAF policies, but it is expected that a high level of SAF policy activity and development will continue over the next decade. Where possible, live weblinks are provided to resources that are anticipated to be updated as circumstances merit.

2. Policy Guidance Task Background

This guidance has been developed by the ICAO Committee on Aviation Environmental Protection (CAEP) based on various studies performed since 2016. These included:

- assessments of existing policy instruments incentivizing deployment of sustainable aviation fuels (SAF);
- review of barriers or disincentives to SAF production;
- identification of potential policies which have been demonstrated to be feasible, effective and practical, based on best practices, lessons learned and proven positive results from the

implementation of those policy instruments, which might include policies developed for other sectors, applicable to air transport;

- identification of common elements and general recommendations to facilitate the implementation of those policies and incentive mechanisms by Member States or regions using effective policy approaches when considered beneficial;

- various techno-economic analysis (TEA) of policy options to foster the deployment of SAF.

Based on these developments, this document summarizes potential policies and coordinated approaches for the deployment of SAF. It completes a toolbox of guidance material for use by ICAO Member States and can be used in combination with the ICAO SAF Rules of Thumb, a set of heuristics that can be utilized to make order-of-magnitude estimations related to SAF costs, investment needs and production potential that could inform policymakers and project developers. The Rules of Thumb are described in more detail in a later section of this document.

3. What defines an effective SAF policy?

SAF production is currently limited by a number of challenges to further development and deployment including:

a) the cost differential with conventional kerosene and the current higher costs of production for SAF;

b) limited availability of cost effective and sustainable SAF feedstock and feedstock production infrastructure;

c) limited investment and high costs of financing of SAF fuel production infrastructure; and,

d) competition for resources and incentives with other sectors (e.g. road transport, renewable power).

As long as the cost of production for SAF is greater than conventional kerosene, feedstock and production infrastructure is not built and SAF is not prioritized, policy intervention will be required to develop SAF production beyond its current small scale.

SAF's economic barriers can be addressed through a range of policy options. As SAF has emerged relatively recently compared to alternative fuels for ground transportation, SAF may need to be included as an 'add-on' to existing renewable fuels policies. The characteristics of effective SAF-enabling policy discussed below reflect what would be considered desirable for any type of renewable fuel policy.

Based on input from ICAO CAEP experts, three key themes influence policy effectiveness:

1. Feasibility: practicable and uncomplicated to implement

2. Effectiveness: successful in producing a desired or intended result

3. Practicality: the policy targets the outcome rather than a theory or set of ideas

Additionally, to be effective, SAF-specific policies/programs should:

- Be stable, predictable and consistent in implementation in order for the private sector to be willing to make investments.

- Be of a sufficient duration to reflect project development timelines (e.g. 10 years or longer provides a degree of predictability for investors/developers).

- Be “stackable” with other incentives – i.e., allowing credit to be received from multiple reinforcing incentives at the same time is helpful.

- Be technology-neutral to enable diverse production pathways and supply chains to develop.

- Link incentives to performance (e.g. higher GHG emission reduction performance should be recognized).

- 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 innovation, 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, subnational government (regions, provinces, states, and localities) may also act in the absence of, or as a complement to, national action.

- Be designed with broad political support/bi-partisan (in two party systems) support to reduce reversal risk. A broad range of benefits including rural development, job creation, environment and technology innovation are common bases of support.

- Be customized to the unique resources, economic and social factors, political barriers and existing regulatory structure. There is no single path to successful SAF policy implementation but considered and customized strategies can be effective.

4. Qualitative metrics for assessing policy effectiveness

A qualitative metric is used by experts to assign ’descriptive’ characteristics containing elements of informed opinion and experience. The qualitative metrics should serve to identify “potential policies” which have been demonstrated to be feasible, effective, and practical.

Eight metrics were identified by CAEP FTG experts to define policy effectiveness. The FTG proposes the following qualitative metrics to be used as a “check-list” instrument for States in evaluating actual or potential policy options, as a tool to assess the feasibility, effectiveness, and practicality of applying such options to their national contexts and conditions. Applying a LOW / MEDIUM / HIGH or simple numerical score to policies using these metrics is a simple effectiveness ranking method.

1) **Flexibility:** Characteristics of this style of policy will demonstrate scope for adjustment to different situations and priorities. Policies with higher flexibility may be able to evolve or adapt quickly. It is possible that special authority may be assigned to monitor and evaluate the policy on an on-going basis. A low flexibility policy, on the other hand, is designed in a rigid manner, implemented for a long-term period, generally remains unchanged, and changes can only be made by high level authorities.

2) **Certainty:** These characteristics relate to the time frame, legal conditions and/or political decisions. Policy certainty is typically important to investors or project stakeholders. Greater policy certainty can be associated with more economic value being ascribed to a particular policy and can be linked to the security level for investors. Lower certainty policies may have the inverse effect for investors and provide less incentive for capital investment. Medium to long-term policy certainty can set investor expectation and will increase investor interest.

3) **Financial costs and benefits:** Policy effectiveness should consider costs and benefits (including social costs). Policies that rely on government financial support should be assessed on the benefits they deliver towards the stated policy objective or for the government.

4) **Price sensitivity to externalities:** The sensitivity of a policy to externalities should be understood before implementation to avoid unintended impacts. Price-based policy can be less volatile if a floor and ceiling price is established. The higher the sensitivity to externalities, the more potential unintended consequences.

5) **Ease of implementation:** Policy implementation can be affected by administrative, governance and procedural issues. The number of agencies involved in implementing or administering a policy can impact effectiveness. States should be conscious of the relationship within their State of local, regional and national jurisdictions and ensure that responsibilities between national, regional and local jurisdictions do not create barriers if policy governance is not clear.

6) **Contribution to Sustainable Aviation Fuel deployment and GHG reduction:** Contribution to commercial deployment of SAF will be higher if a policy sets clear criteria on target quantity of SAF to be deployed, sustainability achievement, commercial parameters and timeframe. This should be supported by a set of legal instruments. Contribution to deployment will be lower if no quantitative target is specified and if not supported by any legal basis. Policies that incentivises greater verified GHG reduction achievement relative to conventional fuels may be more effective. Similarly, a policy that considers, respects and addresses social and economic consequences may deliver broader economic benefits relative to a policy that focuses singularly on environmental achievement.

7) **Unintended consequences:** Effective policies need to address the risk that implementation of the policy could lead to unintended consequences. These consequences can be economic, environmental or social. The most effective policy will have mechanisms to recognise and mitigate the impact of unintended consequences.

8) **Robustness of policy:** Effectiveness of a policy can be influenced by how robust the policy is. Robust policies are ones that, once implemented, have a regulating system to ensure that its objectives are achieved and appropriate procedures have been followed.

5. SAF policy options / examples

Long-term, stable policies are necessary to create a sustained market for SAF. The best policies for SAF development are likely to vary for each State and region based on their unique combination of climate, resources, political, social and economic factors. In the case of States with already well-developed renewable energy policies (e.g. for ground transportation) or carbon legislation, there may be an opportunity for inclusion of SAF in those existing mechanisms. For States that are looking to support renewable energy for the first time, there is an opportunity to take a well thought out and planned approach that best fits a State’s circumstances.

Grouped broadly, policy mechanisms can: 1) Stimulate growth of the SAF Supply (e.g. via R&D, investment, finance); 2) Create SAF demand (e.g. via mandates, subsides and commitments); and, 3) enable the SAF marketplace (e.g. via standards).

A description of policy options and examples follows. A summary of this content also appears in table form in Appendix A. While this list is intended to be comprehensive it should not be taken as exhaustive of all potential policy options.

5.1 Stimulating Growth of SAF Supply

The following policy types are targeted at increasing SAF feedstock and fuel production capacity and supply through R&D, investment, production incentives, and tax treatment.

Policy Category 1: Government funding for SAF research development, demonstration and deployment (RDD&D) to accelerate learning

Government funding can support technology innovation across the SAF supply chain including R&D that reduces SAF costs, enhances sustainability or improves yields in feedstock production, fuel conversion, and logistics of SAF supply chains. Government funding can also support technology demonstration and deployment across the SAF supply chain including direct feedstock promotion and production support.

- OPTION 1.1: Government directed research and development activities
    - This could include government research and directed funding to address barriers to SAF production and use, often with defined target feedstock types and conversion processes. This can help early stage SAF production innovations. It also supports SAF economics by accelerating the learning curve for feedstock yields or production optimisation. Support can occur from establishing specific programs or supporting existing private research activities or through universities or similar institutions.
- OPTION 1.2: Government directed demonstration and deployment activities
    - This could include government research and directed funding to demonstrate and de-risk new feedstock and conversion technologies. Funding can provide support to farmers to establish new crops and to fuel technology providers to scale up and integrate their fuel production. This support accelerates the learning process around technology and supply chain scale up. Support can occur from establishing specific programs that support existing private sector producers.

Policy Category 2: Targeted incentives and tax relief to expand SAF supply infrastructure

SAF production infrastructure is likely to face higher financing costs and requirements due to higher perception of investment risk. Enacting financing programs and tax policies that reduce the financial risk and tax burden of SAF projects will support private sector capital investment in SAF production.

- OPTION 2.1: Capital Grants
    - A government grant given to an entity to build or buy SAF-specific infrastructure. This can support a range of production facilities, transportation, re-fueling or blending infrastructure. Capital grants reduce the financial needs and financial risks of the targeted investment.
- OPTION 2.2: Loan guarantee programs
    - A loan backed by a government institution helps the project financial case, and also reduces overall project risk, making acquiring additional equity of debt easier and lowering the cost of capital.

        - The U.S. Department of Energy’s (DOE) Loan Program Office and the U.S. Department of Agriculture’s (USDA) Biorefinery Assistance Program providing loan guarantees are U.S. examples

        - The Canadian Government’s Innovation, Science, and Economic Development department (ISED) offers repayable and non-repayable funding for R&D and clean tech projects through its Strategic Innovation Fund (SIF) and Net Zero Accelerator (NZA) programs.

- OPTION 2.3: Eligibility of SAF projects for tax advantaged business status

    - For example, master limited partnerships (MLPs) are a specialized U.S. business organization type that is limited in use to the real estate and natural resources sectors (e.g. oil production). MLPs do not pay federal income taxes in the same way that other corporate structures do.

- OPTION 2.4: Accelerated depreciation/‘bonus’ depreciation

    - Accelerated or bonus depreciation allows the accounting write-off of capital investment or the potential to write off more than the actual capital investment. This will result in less expected tax to be paid over the life of the project and improve overall project economics.

- OPTION 2.5: Business Investment Tax Credit (ITC) for SAF investments

    - An 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. This will result in less expected tax to be paid over the life of the project and improve overall project economics.

- OPTION 2.6: Performance-based tax credit

    - The concept consists of a tax credit for a project meeting certain conditions. The credit could be a sliding scale performance credit (higher credit for better GHG performing projects) and should have a defined policy life (i.e. 10-15 years).

- OPTION 2.7: Bonds / Green Bonds

    - Bonds can be issued by private companies, supranational institutions, and public entities including sub-national and local governments to provide low-interest rate and tax exempt financing used to support fuel production infrastructure build out. Green Bonds are designed specifically to support specific climate-related or environmental projects
        - The U.S. States of Nevada and Oregon issued bonds in support of prospective SAF producers Fulcrum Bioenergy and Red Rock Biofuels.

Policy Category 3: Targeted incentives and tax relief to assist SAF facility operation

SAF production facilities are likely to face higher operating costs and risks than existing fuel suppliers that can be addressed through policy mechanisms that provide a boost or support to SAF production via targeted financial incentives or relief from taxes via tax credits. This assists with reducing the cost gap between SAF and fossil jet fuel. They are linked to a specific quantity of fuel produced and made available to the market.

- OPTION 3.1: Blending incentives: Blender’s Tax Credit (BTC)

    - An incentive targeted at the providers or blenders of fuel that provides a credit against taxes. This mitigates the blenders cost of production or purchase difference between SAF and fossil jet.
        - For example, in the U.S. an existing Blender's Tax Credit (BTC) provides a USD 1.00 per gallon incentive for blenders of certain types of biofuel.

- OPTION 3.2: Production incentives: Producer's Tax Credit (PTC)
    - An incentive targeted at the producers of fuels that provides a credit against taxes. This mitigates the cost of production difference between SAF and fossil jet.

- OPTION 3.3: Excise tax credit for SAF
    - For States that tax domestic jet fuel consumption, a reduction or elimination of the tax in proportion to the quantity of SAF consumed serves to incentivize fuel consumers to purchase SAF by contributing to lower SAF cost.
        - For example, in the U.S. an existing domestic commercial and general aviation jet fuel tax funds the Airport and Airways Trust fund on a per gallon basis. This could be eliminated for either unblended (neat) or blended quantities of SAF to incentivize SAF production and use.

- OPTION 3.4: Support for feedstock supply establishment and production
    - SAF production may be limited by availability and cost of the raw material (feedstock) from which it is produced. Targeted support can address the risks and costs to farmers and feedstock suppliers of establishing a new crop and producing it under uncertain conditions. Crop insurance program support for SAF can also be considered in addition to subsidy payments made to farmers aimed at incentivizing production.
        - A U.S. example is the Biomass Crop Assistance Program (BCAP) which offers annual incentive payments and establishment payments to farmers of biomass crops intended for bioenergy production.

Policy Category 4: Recognition and valorization of SAF environmental benefits

SAF production and use may create a number of environmental benefits and ecosystem services that can be recognized and valued under existing and new policies. These could include carbon benefits and greenhouse gas emissions reductions; air quality improvements; and contrail reductions. Additional benefits may be identified going forward.

- OPTION 4.1: Recognize SAF benefits under carbon taxation
    - Where a jurisdiction has introduced a carbon tax, carbon price, or carbon levy (that is setting a tax rate on carbon emissions for each fuel type, thereby providing a signal to reduce emissions) SAF could be rated as either zero or in proportion to the life-cycle greenhouse gas emissions benefit of the particular fuel, thereby subject to reduced tax. This differs from a cap and trade system by not stipulating an overall emission reduction target.

- OPTION 4.2: Recognize SAF benefits under cap-and-trade systems as they develop

    - 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. If SAF were used in such a system, it would exempt or reduce the obligations of the user of the SAF under the regulation. Examples include:

        - Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), where an operator using SAF can reduce its offsetting obligations under the scheme.

        - European Union Emissions Trading System (EU ETS) where an aircraft operator using SAF is exempted from the obligation to surrender allowances.

- OPTION 4.3: Recognize non-carbon SAF benefits: improvements to air quality

    - Some programs and incentives place a value on local air quality. SAF should be able to financially participate in these incentive schemes based on air quality benefits that certain SAFs may be able to provide.

- OPTION 4.4: Recognize non-carbon SAF benefits: reduction in contrails

    - As the understanding of the science evolves, reductions in contrail formation resulting from use of SAF may be able to be recognized for their environmental benefits.

5.2 Creating Demand for SAF

The following policy options are targeted at increasing SAF demand, including creating mandates for SAF use in the transportation fuel supply, providing incentives or subsidies that reduce the cost of SAF for consumers, and voluntary commitments to use SAF.

Policy Category 5: Creation of SAF Mandates

Policies that require SAF to become available as part of the transportation fuels supply can take a number of approaches such as setting volumetric requirements or fuel supply greenhouse gas emission reduction targets. These policies may also obligate different parties such as transportation fuel providers or fuel users. This approach can result in a tradeable or bankable incentive being created that can help to address the cost differential between conventional kerosene and SAF.

- OPTION 5.1: Mandate renewable energy volume requirements in the fuel supply

    - An obligation on fuel providers to provide increasing SAF fuel volumes added to the existing fuel supply on a multi-year schedule creates an incentive for production of more SAF and other fuels which meet the renewable energy definitions of the program. These definitions can include life-cycle greenhouse gas emissions requirements.

        - Variations of this type of policy for road fuels (not SAF) are represented by the EU’s Renewable Energy Directive (RED), the U.S. Renewable Fuels Standard (RFS2), and Canada’s Renewable Fuels Regulation.

        - Variations of this policy for SAF include the ReFuel EU Aviation regulatory proposal in the European Union, Norway's SAF Blending Mandate and Sweden's SAF blending mandate.

- OPTION 5.2: Mandate reduction in carbon intensity of the fuel supply

    - An obligation on fuel providers to reduce the carbon intensity (life-cycle greenhouse gas emissions intensity) of the transportation fuel supply on a multi-year schedule creates an incentive for production of more SAF and other fuels with greenhouse gas benefits. Low carbon fuel standards (LCFS) and clean fuels standards can enable targeting of the carbon intensity of the State's fuel supply.

        - Variation of this type of policy for road fuels are represented by the U.S. State of California Low Carbon Fuel Standard (LCFS), the Canadian Province of British Columbia's Renewable and Low Carbon Fuel Requirements Regulation, and the proposed Canadian Federal Clean Fuels Standard (CFS).

***Policy Category 6: Update existing policies to incorporate* SAF**

Many States may have existing alternative fuel incentive policies at a national level that could incorporate SAF as qualified fuels.

- OPTION 6.1: Incorporating SAF into existing national policies

    - Many national level policies may be adapted to incorporate SAF. Typically, legacy biofuel policies have focused on road-transport-appropriate fuels and do not include SAF as an option. With the more recent advent of drop-in jet fuel/SAF production technologies, an opportunity exists to update existing policies to support SAF production. An examination of the State's existing policies for opportunities to support SAF can be a good starting point.

        - For example in the U.S., SAF has been recognized for credit in the Renewable Fuel Standard (RFS2) as an opt-in fuel. Alterations to the RFS2 policy to more directly recognize and/or require SAF production have been proposed.

- OPTION 6.2: Incorporating SAF into existing sub-national, regional or local policies

    - Similar to the national level, a State may have existing alternative fuel incentive policies at a sub-national, regional or local level that could incorporate SAF as qualified fuels. An update to these existing policies to support SAF production can provide additional support and may enable a beneficial "stacking" of incentives at multiple levels that contributes to SAF economic viability.

        - For example in the U.S., multiple states have established low carbon fuel standards (LCFS) or clean fuels standards designed to reduce the carbon intensity. SAF has been recognized in the States of California, Washington and Oregon as an opt-in fuel. It has also been proposed to alter various aspects of the programs to further incentivize SAF. SAF production in California can count to receive credits in both the national RFS2 and California LCFS programs and "stack" both incentives.

Policy Category 7: Demonstrate government leadership

A clear statement of policy direction and ongoing SAF purchasing are examples of government leadership that can generate ways in which to ramp-up SAF production and use.

- OPTION 7.1: Policy statement to establish direction
  - Setting aspirational goals of specific production or use amounts to signal future intent to develop comprehensive SAF policy measures. This can be linked to the implementation of future policies, sending a signal for project planning. Examples could including State level commitments for a quantitative SAF use goal or carbon reduction by a certain time, or signals from industry such as a commitment to achieve net zero by 2050.
    - Examples from the U.S. includes the 2021 U.S. Aviation Climate Action Plan and SAF Grand Challenge.
- OPTION 7.2: Government commitment to SAF use, carbon neutral air travel
  - A strong demand signal can be created by requiring national, state, local governments, and military to commit to renewable fuel/SAF procurement to reduce environmental impacts of air travel and operations. Governments often have the ability to commit to long term contracts backed by strong credit rating which lowers project risk. Governments can either directly purchase SAF for use by government aircraft or contract with commercial air carriers to provide SAF to power government purchased travel.
    - Examples include Canada’s Low Carbon Fuel Procurement Program which aims to secure a supply of SAF for aircraft operated by the Government of Canada.

5.3 Enabling SAF Markets

Additional activities may be necessary to bring clarity and certainty to enable SAF markets to function optimally.

Policy Category 8: Market enabling activities

Clear standards and methods for certifying the sustainability of feedstock and fuel, as well as calculating, crediting and trading the environmental attributes of SAF will be critical to enabling national and international markets for SAF.

- OPTION 8.1: Adopt clear and recognized sustainability standards and life cycle GHG emissions methods for certification of feedstock supply and fuel production.
  - Recognition of harmonized standards for life cycle GHG calculation and sustainability certification will support broad SAF markets and ensure environmental integrity.
    - National governments (e.g. U.S. RFS2); Regional governments (e.g. EU RED) , international bodies (e.g. ICAO CORSIA); and, industry/non-governmental organizations (e.g. Roundtable on Sustainable Biomaterials (RSB), International Sustainability and Carbon Certification (ISCC) have all developed sustainability certification and GHG emissions methodologies.

- OPTION 8.2: Support development/recognition of systems for environmental attribute ownership and transfer
    - Standard processes and shared systems may facilitate “book and claim” purchasing of SAF that decouples the physical fuel location and the environmental benefit in order to facilitate and promote more efficient and broader use of SAF volumes and their GHG emission reductions.
        - A number of independent pilot programs are underway or in development. These include RSB, World Economic Forum SAF Certificate (WEF SAFc), Smart Freight Center and Massachusetts Institute of Technology’s guidelines (SFC MIT). However, to be effective and to obtain confidence, airline industry and regulators will require a common set of agreed principles, protections against double counting/claiming, and a robust registry.
- OPTION 8.3: Support SAF stakeholder initiatives
    - Stakeholder consultation groups can take many forms and be either government, industry or NGO led. These groups serve a critical function of aligning the diverse stakeholders that make up the SAF supply chain. They can directly coordinate actions and provide critical information and feedback to policymakers.
        - A number of SAF stakeholder groups have provided critical support to the SAF effort. These include the Commercial Aviation Alternative Fuel Initiative (CAAFI) in the U.S.; the Aviation initiative for renewable energy in Gemany (Aireg); the Brazilian Biojetfuel Platform (BBP); and the Nordic Initiative for Sustainable Aviation (NISA), among others. For a listing of the many initiatives see ICAO’s website.

6. Comparative analysis tools

As a means of providing policy makers with high level analysis tools, CAEP puts forward information in the following section on two tools: 1) Rules of Thumb for understanding big picture trends for costs and processing of feedstock and finished SAF that enable order of magnitude estimations; and 2) a discussion of the concept of SAF cost assessment on the basis of marginal abatement cost of CO_2 which allows a policy maker to assess the effectiveness of a specific intervention relative to other alternatives.

6.1 ICAO SAF Rules of Thumb

As part of work of the CAEP Fuels Task Group, CAEP experts from Washington State University and Hasselt University developed a set of heuristics or "Rules of Thumb" for sustainable aviation fuel (SAF) that could be utilized to make order of magnitude estimations related to SAF costs, investment needs and production potential that can be used to inform policymakers and project developers. These SAF Rules of Thumb have been made available on the ICAO SAF Rules of Thumb website.

The Rules of Thumb provide information for three SAF manufacturing technologies that were assessed: Gasification Fischer-Tropsch (GFT), alcohol to jet (ATJ) and hydro-processed esters and fatty acids (HEFA). For each of the technologies, multiple feedstock and two levels of technology maturity were assessed: *n*th plant (production facility with a mature technology) and pioneer plant (first of a kind facility). The Rules of Thumb have been generated by a set of underlying techno-economic analysis (TEA) models developed in support of CAEP. All of the TEA models are based on open-source information about feedstock and fuel conversion technologies. Costs that use proprietary technology may differ significantly.

The Rules of Thumb provide the impact of feedstock cost, fuel yield, facility scale (total distillate and SAF), total capital investment (TCI) and minimum selling price (MSP) for both the *n*th plant and pioneer facility scales.

The Rules of Thumb are intended to provide big picture trends for costs and processing technology/feedstock comparisons and may be utilized to make order of magnitude estimations. However, they *do not provide* precise cost or price information. As such, investment or policy decisions should be based on a dedicated analysis that captures specific details related to the investment or policy.

All of the information in the Rules of Thumb has been calculated using U.S. costs and financial assumptions. The values will change based on regional variables. No incentives were included in the minimum selling price (MSP) values calculated. Summary Tables 1 and 2 provide the most likely costs and facility scales based on the TEA models, existing literature values and expert opinion.

Summary Table 1 - Technology, feedstock type, yield with annual scale (total distillate) and annual SAF production at *n*th plant and pioneer facility scales

Processing Technology	**Feedstock**	**Yield***	**Total Distillate (million L/yr)**		**SAF (million L/yr)**	
			nth	**pioneer**	**nth**	**pioneer**
GFT	MSW	0,31	500	100	200	40
GFT	Forest Residues	0,18	400	100	160	40
GFT	Agricultural Residues	0,14	300	100	120	40
ATJ	Ethanol	0,60	1000	100	700	70
ATJ	Isobutanol - Low	0,75	1000	100	700	70
ATJ	Isobutanol - High	0,75	1000	100	700	70
HEFA	FOGs	0,83	1000	100	549	55
HEFA	Vegetable Oil	0,83	1000	100	549	55

**(weight total distillate/weight dry feedstock)*

Summary Table 2: Pre-processed feedstock cost, total capital investment (TCI) and minimum selling price (MSP) for each technology and feedstock combination for nth plant and pioneer facilities.

Processing Technology	Feedstock	Feedstock Cost ($/tonne)	Feedstock Cost ($/L)	TCI (million $)		MSP ($/L)	
				nth	pioneer	nth	pioneer
GFT	MSW	0	-	1170	724	0,7	1,8
GFT	Forest Residues	125	-	1636	1063	1,8	3,3
GFT	Agricultural Residues	110	-	1506	1238	2,1	3,8
ATJ	Ethanol	456	0.36	333	99	0,8	1,0
ATJ	Isobutanol - Low	1110	0.89	343	67	1,3	1,4
ATJ	Isobutanol - High	1496	1.20	424	75	1,8	1,9
HEFA*	FOGs	580	-	428	112	0,8	1,0
HEFA*	Vegetable Oil	809	-	431	108	1,1	1,2

**HEFA feedstock are not pre-processed.*

Graphical representations of these numbers, additional graphics and underlying data spreadsheet behind the Rules of Thumb are available at the ICAO SAF Rules of Thumb website.

6.2 How to determine the marginal abatement cost of CO_2 mitigation from using SAF?

The aviation sector is seeking ways to reduce or abate emissions. Some options such as replacing older fleet or improving operational performance (e.g. winglets, lighter onboard materials) have a clear economic benefit. Less fuel consumption means a reduced operating cost, while also delivering an environmental benefit. Historically, airlines have not required a policy intervention to make such changes; however, the environmental performance improvement has been limited to around 2% per annum.

More substantial CO_2 reduction can come from a reduced life-cycle fuel. Current knowledge suggests that SAF has the greatest potential to deliver significant industry wide CO_2 reductions. This confidence is supported by a clear understanding of feedstock potential under necessary sustainability constraints and the technology readiness of SAF being high. Additionally, SAF is a drop-in fuel, meaning no adaptation to airframes, engines, or fuel storage or delivery infrastructure is required. This makes a cost assessment of SAF on a CO_2 basis relatively simple. Understanding this can be valuable for a policy maker to assess the effectiveness of a specific intervention relative to other alternatives.

This illustrative example explains the process for determining the *per tonne of* CO_2 cost from using SAF under a set of assumptions.

Example:

Airline XYZ requires 10 tonnes of jet fuel per annum and decides to use SAF to reduce its emissions. The airline makes a decision to use 8 tonnes of conventional kerosene and 2 tonnes of SAF.

<u>Assumptions:</u>

Cost of 1 tonne of conventional kerosene = $600

Cost of 1 tonne of SAF = $1100

Jet fuel combustion CO_2 emissions factor = 3.16

CO_2 emissions reduction factor of this SAF = 80%

Firstly, the amount of CO_2 reduced must be determined which is a function of the amount of SAF used, the jet fuel combustion factor and the SAF emissions reduction factor.

Net CO_2 emissions reduction = 2 tonnes * 3.16 * 80% = 5.06 tonnes CO_2

The cost per tonne of CO_2 reduced is found by calculating the cost difference between SAF and conventional kerosene divided by the amount of CO_2 reduced.

Cost per tonne of CO_2 reduced = 2 tonnes * (1100-600) / 5.06 = $197.78 / tonne

Given the above, how does the cost of SAF compare to aviation use of hydrogen or electric? Hydrogen and electric power are non-drop in fuel alternatives. This means changes are necessary for either aircraft, engines, or airports including fuel systems and storage facilities. This makes a CO_2 based cost effectiveness assessment of different abatement options complex.

To determine the per tonne of CO_2 cost reduction from hydrogen it is necessary to have reliable data on:

- The cost of product for hydrogen.
- The cost of a new or modified aircraft (hydrogen compatible).
- The operating economics of a hydrogen aircraft (for example, expected block hours, maintenance cycles, certification costs).
- The cost of new or modified fuel storage and fuel delivery infrastructure.

These complexities mean that comparing the effectiveness of policy interventions for hydrogen and electric will be more complex for the medium term. However, the SAF CO_2 abatement cost method can serve as a useful benchmark as better information for non-drop-in fuel alternatives develops and for comparing against different out-of-sector solutions such as offsets, carbon capture, utilization and storage or direct air capture.

7. How Do Policies Impact SAF Project Economics?

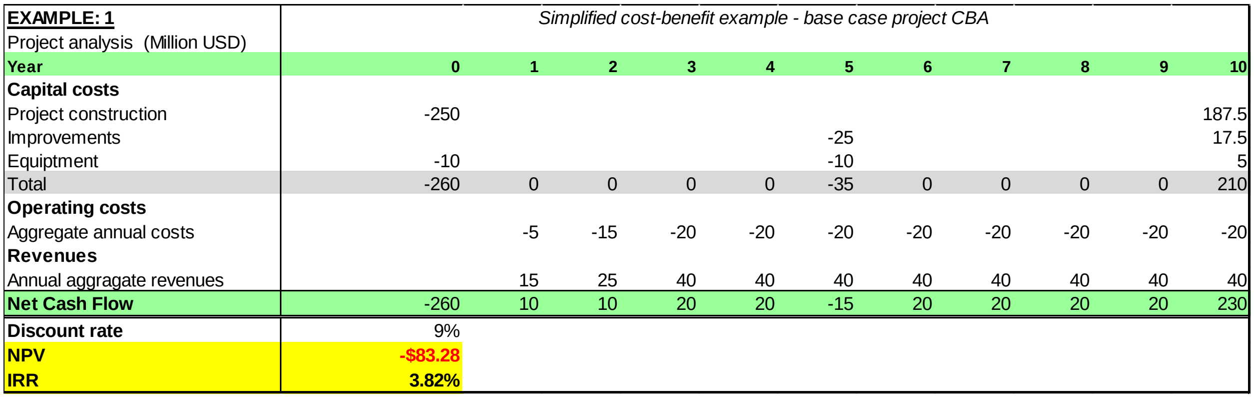
Simple illustrative examples can be useful to examine and understand how a policy might influence the profitability of a SAF project. Examples can particularly help to expose the differences in impact between a policy that applies towards the start of the project and a policy that provides smaller support over the life over the project.

The below five examples demonstrate the sensitivity of a hypothetical project to small changes in the input assumptions. Specifically, they highlight how policy can be applied to influence a project’s financial viability. It is important to note that these examples purely examine a project from the perspective of the project owner. While a ‘real life’ project will have significantly more line items and additional complexity, these examples provide an illustration of how policy decisions could impact the project’s economic merit.

The analysis metric used is Net Present Value (NPV). NPV is a central tool in discounted cash flow (DCF) analysis and is a standard method for using the time value of money to appraise long-term projects. Equally, it would be possible to determine what amount of revenue would be required (e.g. minimum selling price of the SAF) to achieve a positive NPV.

Example 1:

Example 1 is a base case scenario. This is an example where purchasing land, equipment and constructing a SAF refining plant costs $260 million. Both operating costs and revenues ramp up, then remain consistent from year 3. In a real world scenario these are not likely to be linear but this does not impact the example. A discount rate of 9% is used. This is the rate that must be achieved to deliver a NPV of $0. This example delivers a forecast NPV of -$83.28 million or an internal rate of return (IRR) on the funds employed of 3.82%. This does not meet the hurdle rate (of 9%) hence a rational firm would not undertake this project.



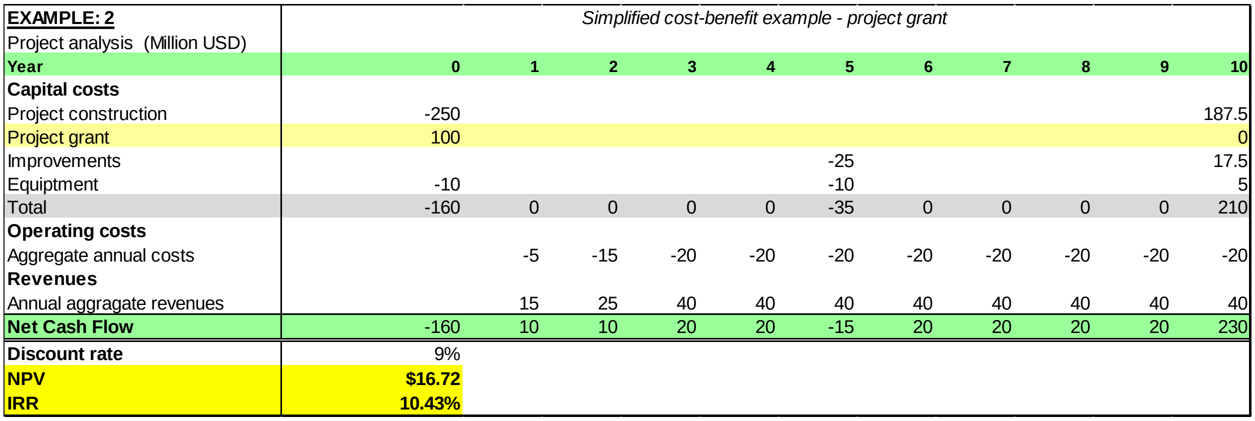
EXAMPLE: 1	*Simplified cost-benefit example - base case project CBA*										
Project analysis (Million USD)											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital costs											
Project construction	-250										187.5
Improvements						-25					17.5
Equiptment	-10					-10					5
Total	-260	0	0	0	0	-35	0	0	0	0	210
Operating costs											
Aggregate annual costs		-5	-15	-20	-20	-20	-20	-20	-20	-20	-20
Revenues											
Annual aggragate revenues		15	25	40	40	40	40	40	40	40	40
Net Cash Flow	-260	10	10	20	20	-15	20	20	20	20	230
Discount rate	9%										
NPV	**-$83.28**										
IRR	**3.82%**										

Example 2

Example 2 replicates example 1, except in this case a project grant of $100 million is received. This could be a government grant. A grant is often contingent on satisfying certain criteria, however in this case it is assumed that this criterion is met and the funds are received without attached conditions.

While the aggregate of the grant is only 2.5 years of projected revenue, it represents 40% of the total assumed construction cost. The advantage of receiving these funds at project inception is significant, particularly with high discount rates.

This change to the project delivers a $16.72 million positive NPV at an IRR of 10.43%. A rational firm would undertake this project.



EXAMPLE: 2	*Simplified cost-benefit example - project grant*										
Project analysis (Million USD)											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital costs											
Project construction	-250										187.5
Project grant	100										0
Improvements						-25					17.5
Equiptment	-10					-10					5
Total	-160	0	0	0	0	-35	0	0	0	0	210
Operating costs											
Aggregate annual costs		-5	-15	-20	-20	-20	-20	-20	-20	-20	-20
Revenues											
Annual aggragate revenues		15	25	40	40	40	40	40	40	40	40
Net Cash Flow	-160	10	10	20	20	-15	20	20	20	20	230
Discount rate	9%										
NPV	**$16.72**										
IRR	**10.43%**										

Example 3:

Example 3 replicates Example 1, except in this case the firm acquires an interest free loan for 10 years of 100 million. This could be provided from a government program and when the project is more mature this debt could easily be refinanced and repaid. Further, conceptually the idea of an interest free loan could be substituted with non-dilutive equity.

While the project NPV remains negative at -$25.52 million it is substantially improved on example 1. Further, the IRR of 6.37% may be feasible for some investors.

EXAMPLE: 3	*Simplified cost-benefit example - interest free loan*										
Project analysis (Million USD)											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital costs											
Project construction	-250										187.5
Interest free loan	100										-100
Improvements						-25					17.5
Equiptment	-10					-10					5
Total	-160	0	0	0	0	-35	0	0	0	0	110
Operating costs											
Aggregate annual costs		-5	-15	-20	-20	-20	-20	-20	-20	-20	-20
Revenues											
Annual aggragate revenues		15	25	40	40	40	40	40	40	40	40
Net Cash Flow	-160	10	10	20	20	-15	20	20	20	20	130
Discount rate	9%										
NPV	**-$25.52**										
IRR	**6.37%**										

Example 4:

Example 4 replicates example 1, however in this case the SAF supplier receives a subsidy. While in this case the subsidy is not sufficient to generate a positive project NPV, it demonstrates that the annual subsidy improves the forecast IRR from 3.82% in example 1 to 5.23% in example 4.

EXAMPLE: 4	*Simplified cost-benefit example - revenue subsidy*										
Project analysis (Million USD)											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital costs											
Project construction	-250										187.5
Improvements						-25					17.5
Equiptment	-10					-10					5
Total	-260	0	0	0	0	-35	0	0	0	0	210
Operating costs											
Aggregate annual costs		-5	-15	-20	-20	-20	-20	-20	-20	-20	-20
Revenues											
Subsidy		1.5	2.5	4	4	4	4	4	4	4	4
Annual aggragate revenues		15	25	40	40	40	40	40	40	40	40
Net Cash Flow	-260	11.5	12.5	24	24	-11	24	24	24	24	234
Discount rate	9%										
NPV	**-$61.16**										
IRR	**5.23%**										

Example 5:

Example 5 incorporates some of the policy features of the other examples. It includes a revenue subsidy of 10% of revenues, a project grant of $50 million and an interest free loan of $100 million repayable in 10 years.

This example clearly demonstrates how combining some policy mechanisms can make an otherwise unattractive project successful. Example 5 generates a forecast NPV of $46.59 million at an IRR of 15.1%. Even at a discount rate of 9% this project is comfortably acceptable. This shows how when connected stakeholders such as the project owner and operator, the government, product demand e.g. an airline and debt financiers work collaboratively, policy mechanisms can combine to build a strong business case.

EXAMPLE: 5 Project analysis (Million USD)	*Simplified cost-benefit example - project grant*									
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Capital costs											
Project construction	-250										187.5
Project grant	50										0
Interest free loan	100										-100
Improvements						-25					17.5
Equiptment	-10					-10					5
Total	-110	0	0	0	0	-35	0	0	0	0	110
Operating costs											
Aggregate annual costs		-5	-15	-20	-20	-20	-20	-20	-20	-20	-20
Revenues											
Subsidy		1.5	2.5	4	4	4	4	4	4	4	4
Annual aggragate revenues		15	25	40	40	40	40	40	40	40	40
Net Cash Flow	-110	11.5	12.5	24	24	-11	24	24	24	24	134
Discount rate	9%										
NPV	**$46.59**										
IRR	**15%**										

It should be assumed that subsidies either reduce or ‘fade out’ over time. If this is articulated by policy makers it does not need to impact project feasibility. It is assumed that both the technology learning curve and project economies of scale will reduce the unit cost of production over time, thus reducing the reliance on subsidies. Interest free loans or project grants simply tackle the high discount rate conundrum at the start of a capital intense project in an embryonic industry.

8. How Do Policies Impact SAF Minimum Selling Price?

To examine and understand how policy might influence the sales price of SAF for a SAF producer, it can be useful to look at an illustrative example. This analysis from the U.S. context helps to demonstrate how the benefit of the stacking of multiple policy mechanisms can be an effective way to move SAF minimum selling price (MSP) toward price parity with conventional kerosene. Minimum selling price (MSP) is the fuel selling price that aligns with the target real discount rate and an NPV of zero. The five examples in this section illustrate the possible impact of policies on MSP with a target real discount rate of 10%. The calculations are for an example facility and do not model a specific facility or include any proprietary information. As such, the MSP should not be taken as absolute. The impact of policies on each conversion technology and feedstock combination will be different as a result of widely varying capital and operating costs. The included examples demonstrate the impact of incentive policies on a hypothetical Fischer-Tropsch facility that uses woody biomass as feedstock with costs, economic variables and incentives from the U.S. The following examples demonstrate that stacking of incentives can be an effective way to move SAF MSP toward price parity with conventional kerosene. All analysis is for mature, nth plant economics unless otherwise stated.

In the U.S. there are multiple policy incentives used to promote investment in renewable fuels. The Renewable Fuel Standard (RFS2) is a federal program that issues Renewable Identification Numbers (RINs) for each gallon of fuel produced (note the analysis below pro-rates this value for liters). Multiple RIN types exist, and each has a percent CO_2e reduction threshold and a monetary value which is paid to the fuel producer as taxable income. For the examples here, all RINs considered are for cellulosic biofuels also known as D3 RINs.

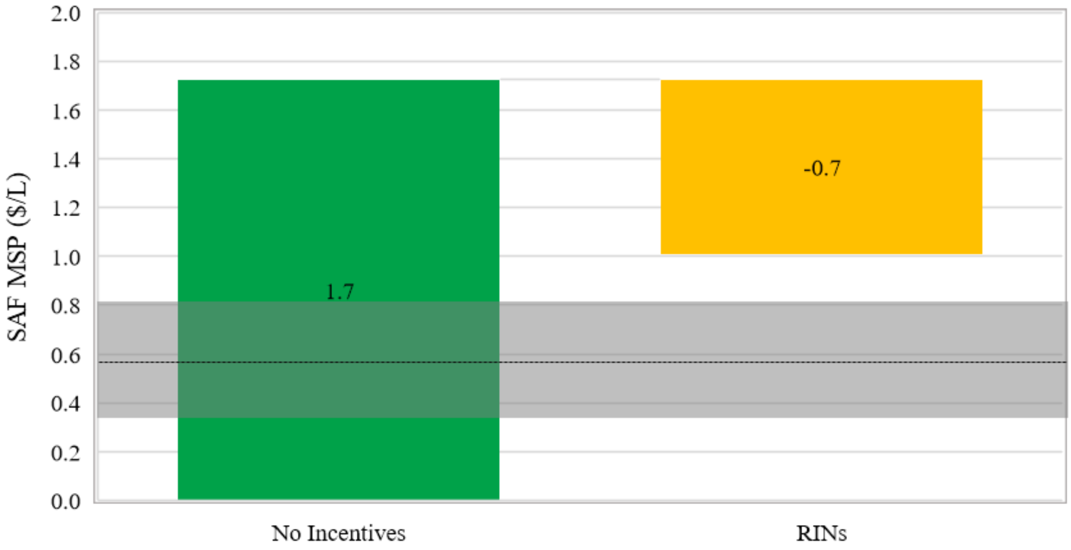
Blenders Tax Credits are a second type of federal incentive that is paid to the blender as a reduction of taxes to zero and then as untaxable income. In the U.S. this type of incentive exists for most fuel types, but is waiting for legislative approval for SAF. The examples with this incentive include both the existing and proposed legislation with incentives for 10-years and assume that the producer and blender are the same entity.

State or regional incentives currently drive fuel to a compressed part of the U.S. California's Low Carbon Fuel Standard (LCFS), an incentive that scales based on carbon intensity score is included in some of the examples.

Capital grants, an incentive with the intended purpose of helping finance new technology is included in an example. The reduction in capital costs lowers MSP, while also reducing the risk to investors.

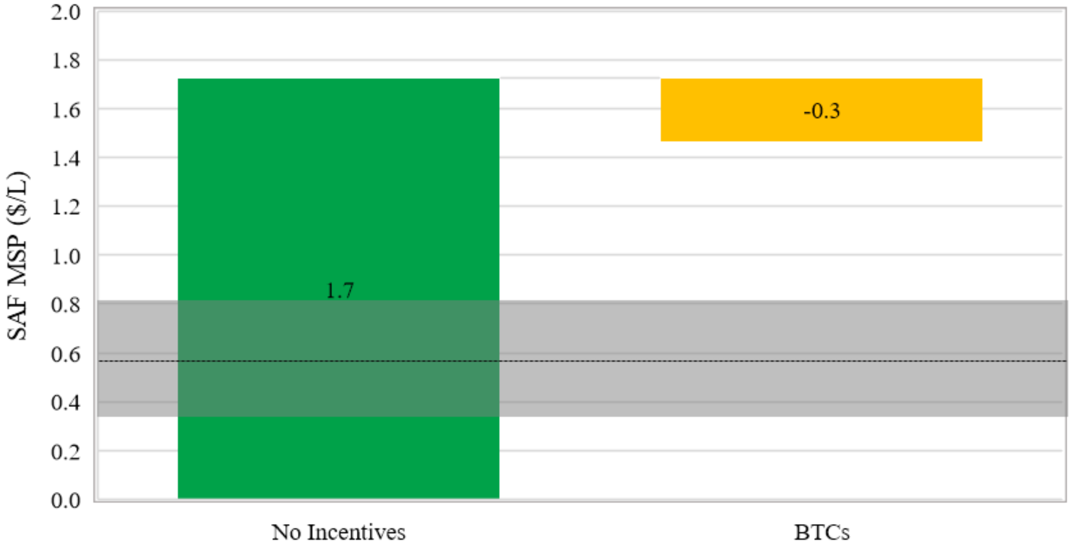
Example 1:

Example 1 illustrates the possible reduction in SAF MSP for the example facility with the addition of RFS RINs. The values of RINs vary, an average value was applied for the years 2014 through 2020. The estimated MSP will vary with the current market value of RINs. The grey band on each chart is the range of annual average wholesale conventional kerosene prices from 2011-2020 and the dotted line is the average value (EIA 2021). The RFS incentive package is not enough to reduce the MSP into the range of conventional kerosene.



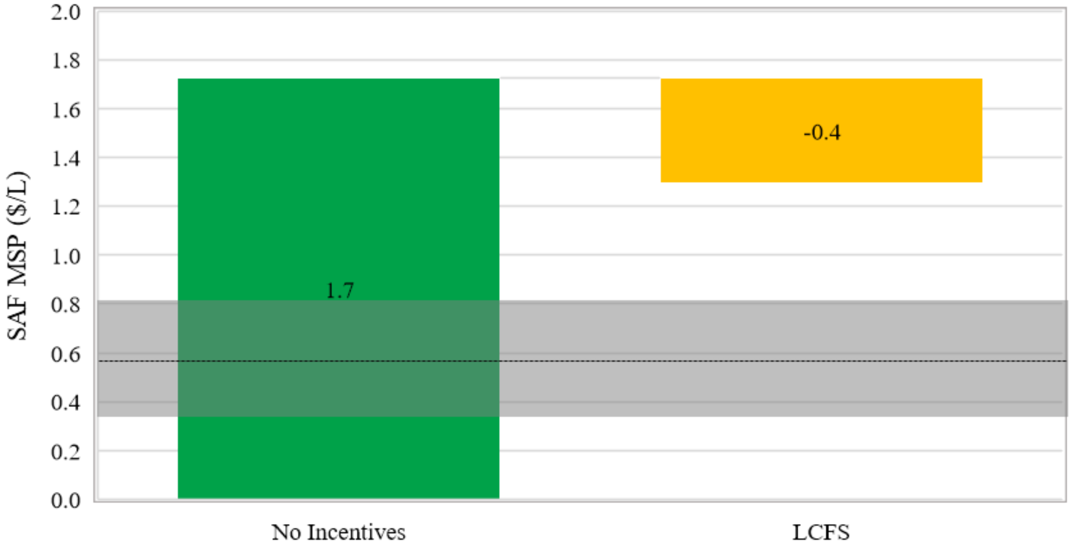
Example 2:

Example 2 replicates example 1, but instead of looking at the impact of RINs, the MSP reduction from blender tax credits is quantified. Once again, this incentive is not enough to bring the SAF MSP into the conventional kerosene range.



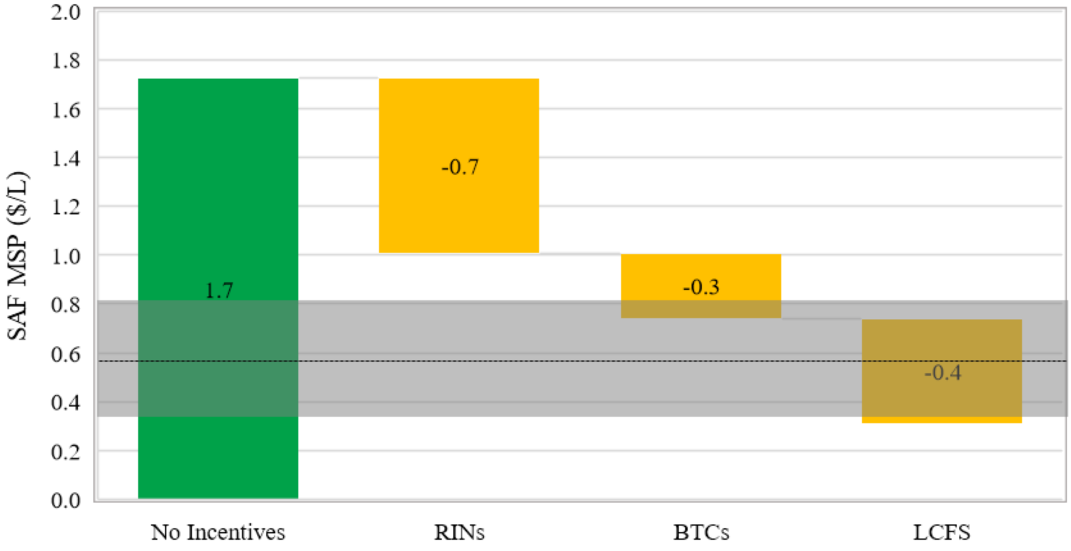
Example 3:

Example 3 mimics examples 1 and 2, but instead of RINs or BTC, the change in MSP from the addition of California's LCFS is estimated. The SAF MSP from the LCFS does not reduce enough to drop the SAF MSP within the price parity range with conventional kerosene.



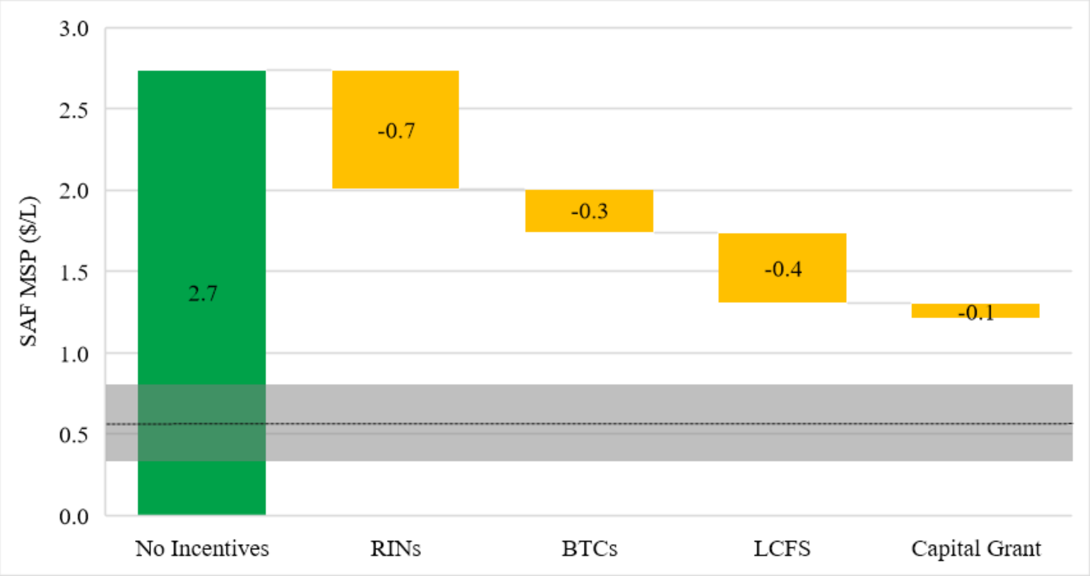
Example 4:

Example 4 is a combination of examples 1 through 3, with all of the incentives stacked together. For the estimated incentive values, the combination of either BTCs or LCFS with RINs brings the MSP to the top of the conventional kerosene price range. However, it is unlikely that investments will be made unless the MSP drops below the average line. The MSP drops below this level with the combination of all three incentives.



Example 5:

Example 5 starts with a baseline (no incentives) MSP for a pioneer plant. The pioneer plant assumption increases the capital cost per liter of fuel and decreases the total plant fuel output. For the technology assessed in this example, this MSP is more relevant to the current state of technology development. The incentives from examples 1 through 3 are added as well as a capital grant of 75 million USD. The combination of all of the four incentives is not enough to drop the pioneer MSP into the conventional kerosene range. The impact of the capital grant is small, the scale of the capital investment needed for a pioneer Fischer-Tropsch, woody biomass plant is too great for 75 million USD to overcome.



The incentives discussed are for illustrative purposes only and it is understood that the values of these incentives will vary with location and time. The findings do show that multiple incentives (or one very large incentive) are required to achieve price parity for nth plant facilities. However, pioneer technology will require additional funding beyond what was discussed to meet this goal.

9. Resources

A list of useful web resources and references is appended here:

Air Transport Action Group – Waypoint 2050

Air Transport Action Group – Fueling Net Zero: How the aviation industry can deploy sufficient sustainable aviation fuel to meet climate ambitions

Alternative Fuels Data Center – U.S. Federal and State Laws and Incentives

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

California Air Resources Board - Low Carbon Fuel Standard

Canada - Clean Fuel Standard

European Union - Renewable Energy Directive

European Union - ReFuel EU

ICAO - Sustainable Aviation Fuels

ICAO - Sustainable Aviation Fuels Guide

ICAO - SAF Rules of Thumb

Frontiers in Energy Research Special Topic on SAF

United States - Renewable Fuel Standard Program

United States - SAF Grand Challenge

World Economic Forum - Clean Skies for Tomorrow: Joint policy proposal to accelerate the deployment of sustainable aviation fuels in Europe

World Economic Forum – Clean Skies for Tomorrow Sustainable Aviation Fuel Policy Toolkit

10. Glossary of Terms

Aireg	Aviation Initiative for Renewable Energy in Germany
ATJ	Alcohol-to-Jet
BBP	Brazilian Biofuels Platform
BCAP	Biomass Crop Assistance Program
BTC	Blenders Tax Credit
CAEP	Committee on Aviation Environmental Protection
CAAFI	Commercial Aviation Alternative Fuels Initiative
CARB	California Air Resource Board
CEF	CORSIA Eligible Fuel
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CO2	Carbon Dioxide
DOE	U.S. Department of Energy
DSHC	Direct Sugar to Hydrocarbons
EU	European Union
EU RED	European Union Renewable Energy Directive
EU ETS	European Union Emission Trading Scheme
FAA	Federal Aviation Administration
FT	Fischer-Tropsch
FTG	Fuels Task Group
GFAAF	Global Framework for Aviation Alternative Fuels
GFT	Gasification Fischer-Tropsch
GHG	Greenhouse Gas
HEFA	Hydroprocessed Esters and Fatty Acids
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISCC	International Sustainability & Carbon Certification
ITC	Investment Tax Credit
LCA	Life Cycle Assessment
LCAF	Lower Carbon Aviation Fuels
LCFS	Low Carbon Fuel Standard

LUC	Land Use Change
MLP	Master limited partnership
MSW	Municipal Solid Waste
MSP	Minimum Selling Price
NISA	Nordic Initiative for Sustainable Aviation
NPV	Net Present Value
PTC	Production Tax Credit
RDD&D	Research Development, Demonstration and Deployment
RFS / RFS2	Renewable Fuel Standard
RINs	Renewable Identification Numbers
RSB	Roundtable on Sustainable Biomaterials
SAF	Sustainable Aviation Fuels
SCS	Sustainability Certification Schemes
SPK	Synthetic Paraffinic Kerosene
SIP	Synthetic Iso-paraffin SPK Synthesized Paraffinic Kerosene
TEA	Techno-economic analysis
USDA	U.S. Department of Agriculture
WEF	World Economic Forum

Appendix A – Table of SAF Policy Options

Impact Area	Policy Category	Policy Option	Description
Stimulating Growth of SAF Supply	**1 - Government funding for SAF research, development, demonstration and deployment (RDD&D) to accelerate learning**	1.1 - Government R&D	Government research and funding to address barriers to SAF production and use can help early stage SAF production innovations. It also supports SAF economics by accelerating the learning curve for feedstock yields or production optimisation. Support can occur from establishing specific programs or supporting existing private research activities or through universities or similar institutions.
		1.2 - Government demonstration and deployment	Government research and funding to demonstrate and de-risk new feedstock and conversion technologies can provide support to both feedstock and fuel technology providers to scale up and integrate their production. This support accelerates the learning process around technology and supply chain scale up. Support can occur from establishing specific programs that support existing private sector producers.
	2 - Targeted incentives and tax relief to expand SAF supply infrastructure	2.1 - Capital grants	A government grant given to an entity to build or buy SAF-specific infrastructure. This can support a range of production facilities, transportation, re-fuelling or blending infrastructure. Capital grants reduce the financial needs and financial risks of the targeted investment.
		2.2 - Loan guarantee programs	A loan backed by a government institution helps the project financial case, and also reduces overall project risk, making acquiring additional equity of debt easier and lowers cost of capital.
		2.3 - Eligibility of SAF projects for tax advantaged business status	For example master limited partnerships (MLPs) are a specialized U.S. business organization type that is limited in use to the real estate and natural resources sectors (e.g. oil production). MLPs do not pay federal income taxes in the same way that other corporate structures do.
		2.4 - Accelerated depreciation/'bonus' depreciation	Accelerated or bonus depreciation allows the accounting write-off of capital investment or the potential to write off more than the actual capital investment. This will result in less expected tax to be paid over the life of the project and improve overall project economics.
		2.5 - Business Investment Tax Credit (ITC) for SAF investments	An 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. This will result in less expected tax to be paid over the life of the project and improve overall project economics.
		2.6 - Performance-based tax credit	The concept offers a tax credit for a project meeting certain conditions. The credit could be a sliding scale performance credit (higher credit for better GHG performing projects) and should have a defined policy life (i.e. 10-15 years).
		2.7 – Bonds / Green Bonds	Bonds can be issued by private companies, supranational institutions, and public entities including sub-national and local governments to provide low-interest rate and tax exempt financing used to support fuel production infrastructure build out. Green Bonds are designed specifically to support specific climate-related or environmental projects.
	3 - Targeted incentives and tax relief to assist SAF facility operation	3.1 Blending incentives: Blender's Tax Credit	An incentive targeted at the providers or blenders of fuel that provides a credit against taxes. This mitigates the blenders cost of production or purchase difference between SAF and fossil jet.
		3.2 – Production incentives: Producer's Tax Credit	An incentive targeted at the producers of fuels that provides a credit against taxes. This mitigates the cost of production difference between SAF and fossil jet.
		3.3 - Excise tax credit for SAF	For States that tax domestic jet fuel consumption, a reduction or elimination of the tax in proportion to quantity of SAF consumed serves to incentivize fuel consumers to purchase SAF by contributing to lower SAF cost.
		3.4 - Support for feedstock supply establishment and production	Targeted support can address the risks and costs to farmers and feedstock suppliers of establishing a new crop and producing it under uncertain conditions. Crop insurance program support for SAF can also be considered in addition to subsidy payments made to farmers aimed at incentivizing production.

	4 - Recognition and valorization of SAF environmental benefits	4.1 – Recognize SAF benefits under carbon taxation	Where a jurisdiction has introduced a carbon tax, carbon price, or carbon levy (that is setting a tax rate on carbon emissions for each fuel type, thereby providing a signal to reduce emissions) SAF could be rated as either zero or in proportion to the life-cycle greenhouse gas emissions benefit of the particular fuel, thereby subject to reduced tax. This differs from a cap and trade system by not stipulating an overall emission reduction target
		4.2 - Recognize SAF benefits under cap-and-trade systems	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. If SAF were used in such a system, it would exempt the user of the SAF of obligations under the regulation.
		4.3 - Recognize non-carbon SAF benefits: improvements to air quality	Some programs and incentives place a value on local air quality. SAF should be able to financially participate in these incentive schemes based on air quality benefits that certain SAFs may be able to provide.
		4.3 - Recognize non-carbon SAF benefits: reduction in contrails	As the understanding of the science evolves, reductions in contrail formation resulting from use of SAF may be able to be recognized for their environmental benefits.
Creating Demand for SAF	**5- Creation of SAF mandates**	5.1 - Mandate renewable energy volume requirements in the fuel supply	An obligation on fuel providers to provide increasing SAF fuel volumes added to the existing fuel supply on a multi-year schedule creates an incentive for production of more SAF and other fuels which meet the renewable energy definitions of the program. These definitions can include life-cycle greenhouse gas emissions requirements.
		5.2 - Mandate reduction in carbon intensity of the fuel supply	An obligation on fuel providers to reduce the carbon intensity (life-cycle greenhouse gas emissions intensity) of the transportation fuel supply on a multi-year schedule creates an incentive for production of more SAF and other fuels with greenhouse gas benefits. Low carbon fuel standards (LCFS) and clean fuels standards can enable targeting of the carbon intensity of the State's fuel supply.
	6 - Update existing policies to incorporate SAF	6.1: Incorporating SAF into existing national policies	Many national level policies may be adapted to incorporate SAF. Typically, legacy biofuel policies have focused on road-transport-appropriate fuels and do not include SAF as an option. With the more recent advent of drop-in jet fuel/SAF production technologies, an opportunity exists to update existing policies to support SAF production.
		6.2: Incorporating SAF into existing sub-national, regional or local policies	Existing alternative fuel incentive policies at a sub-national, regional or local level may be abler to to incorporate SAF as qualified fuels. An update to these existing policies to support SAF production can provide additional support and may enable a beneficial "stacking" of incentives at multiple levels that contributes to SAF economic viability.
	7 – Demonstrate government leadership	7.1 Policy statement to establish direction	Setting aspirational goals of specific production or use amounts to signal future intent to develop comprehensive SAF policy measures. This can be linked to the implementation of future policies, sending a signal for project planning. Examples could including State level commitments for a quantitative SAF use goal or carbon reduction by a certain time, or signals from industry such as a commitment to achieve net zero by 2050.
		7.2: Government commitment to SAF use, carbon neutral air travel	A strong demand signal can be created by requiring national, state, local governments, and military to commit to renewable fuel/SAF procurement to reduce environmental impacts of air travel and operations. Governments often have the ability to commit to long term contracts backed by strong credit rating which lowers project risk. Governments can either directly purchase SAF for use by government aircraft or contract with commercial air carriers to provide SAF to power government purchased travel.
Enabling SAF Markets	**8 - Market enabling activities**	8.1 - Adopt clear and recognized sustainability standards and life cycle GHG emissions methods for certification of feedstock supply and fuel production	Use of clear standards and harmonized methods for life cycle GHG emissions calculation and sustainability certification will support broad SAF markets and ensure environmental integrity.

		8.2 - Support development/recognition of systems for environmental attribute ownership and transfer	Standard processes and shared systems for calculating, crediting and trading the environmental attributes of SAF may facilitate “book and claim” purchasing of SAF that decouples the physical fuel location and the environmental benefit in order to facilitate and promote more efficient and broader use of SAF volumes and their GHG emission reductions.
		8.3 - Support SAF stakeholder initiatives	Stakeholder consultation groups can take many forms and be either government, industry or NGO led. These groups serve a critical function of aligning the diverse stakeholders that make up the SAF supply chain. They can directly coordinate actions and provide critical information and feedback to policymakers.

Appendix B – Policy Approach Example: European policy developments - Fit for 55: ReFuel EU

The ReFuelEU policy has been developed to address European aviation emissions. The Commission has expressed clear intent through the draft legislation to use a mandate policy as the primary mechanism to accelerate the development and deployment of SAF.

Introduction of an EU wide SAF mandate:

In the context of ReFuelEU, this policy option suggests imposing an obligation on fuel suppliers to supply physically at least a minimum share of SAF (expressed in volume terms) at all EU airports at all times.

Some airports, such as remote or insular airports may request to be out of the scope. This means that every liter of jet fuel supplied to airports must be blended with a minimum share of SAF from 2025 onwards.

Airlines operating on intra-EU and extra-EU routes would have no alternative than to use SAF-blended jet fuel when departing from EU airports. The proposed monitoring, reporting and verification mechanism of the fuel supply obligation would be ensured through the dedicated mechanisms under RED II, i.e. the Union Database established under RED II Article 28.

An existing EU agency (e.g. European Aviation Safety Agency EASA), is required to compile the information provided on SAF supply under the Union Database and reports to the Commission on the compliance of each fuel supplier with their supply obligation. Penalties imposed on fuel suppliers in case of non-compliance are determined at EU level, reviewed yearly if needed, and enforced at national level. Funds collected from penalties are reinjected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

What are some of the possible mandate policy option variations?

a) Target setting vs CO_2 reduction.

This would impose on fuel suppliers a minimum reduction of the CO_2 intensity (meaning the lifecycle CO_2 emissions per unit of energy) of the overall jet fuel supplied rather than just using a certain quantity of SAF. The aim is to take a technology-neutral approach by using the CO_2 intensity reduction-based obligation.

b) Obligation on the demand side (intra and extra-EU scope)

This policy option would consist of imposing an obligation on airlines to use a minimum share of SAF (expressed in volume terms) as part of their total jet fuel use on intra-EU flights and flights from any EU airport to an extra-EU airport. An airline is not strictly required to use SAF on each flight as long as it can demonstrate that it has used the minimum share of SAF on average over the course of each reporting period of one year. As some airlines may not have physical access to SAF at the airports where they focus their operations, a transaction system allows them to purchase SAF and claim their use even if they do not use it physically, provided that it is used elsewhere in the EU aviation system. Such a system would not require any additional IT structure or services (it would work under the EU ETS) and would represent a very limited number of transactions by airlines on a yearly basis, hence negligible administrative costs. An existing European organisation (e.g. Eurocontrol) is required to compile the information contained in the EU ETS and CORSIA emission reports regarding SAF use, and reports to the Commission on the compliance of individual airlines with their SAF use obligation. Penalties imposed on airlines in case of non-compliance are determined at EU level, reviewed on a yearly basis if needed, and enforced at national level. Funds collected from penalties are injected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

c) Obligation on the demand side (intra-EU scope)

This mandate option would contain the scope to cover only intra-EU flights. This means that an obligation is imposed on airlines to use a minimum share of SAF (expressed in volume terms), as part of their total jet fuel consumption on intra-EU flights only. Airlines operating such flights would need to use a larger portion of SAF to compensate for excluding extra EU scope flights. If not, this option would result in lower emissions reductions achievement from intra- and extra-EU air transport than all other options. Monitoring, reporting and verification of SAF use by airlines is ensured through the dedicated mechanisms under the EU ETS Monitoring and Reporting Regulation, meaning that airlines operating intra-EU flights report SAF use within their individual emissions reports

d) Obligation on supply and uplift

Fuel suppliers are obliged to supply physically a minimum share of SAF (expressed in volume terms) at all EU airports at all times, post-2035 (following a transition period). Certain categories of airports, such as small airports could be exempted. This should be done by setting a threshold e.g. on the volume of traffic per airport. This means that every litre of jet fuel supplied to airports must be blended with at least a minimum share of SAF. Airlines (EU and non-EU) operating on intra-EU and extra-EU routes taking off from airports located on EU territory have no alternative than to use SAF-blended jet fuel. This minimum share of SAF to be supplied corresponds to the trajectory of the SAF market ramp up in the mandate provision.

e) Obligation on supply and uplift (CO_2 intensity reduction approach)

This obligation imposes on fuel suppliers a minimum reduction of the CO2 intensity of the overall jet fuel supplied.

Common elements for all policy options:

i. Types of SAF supported and sustainability requirements:

Under all policy options, eligible SAF is restricted to the following types of ASTM-certified drop-in fuels, where compliance with the RED II sustainability framework can be demonstrated:

- "Biofuels" produced from feedstock listed in Part B of Annex IX, in the meaning of Article 2(33) of the Renewable Energy Directive.
- "Advanced biofuels" in the meaning of Article 2(34) of the Renewable Energy Directive (Annex IX Part A).
- "Renewable fuels of non-biological origin" (RFNBOs), in the meaning of Article 2(36) of the recast Renewable Energy Directive. For this initiative, the synthetic liquid fuels are relevant.

ii. Volume-based approach.

In the case of a volume based obligation including sub-mandate provisions, this approach is moderately technology-neutral and it is generally associated with enabling technology choices. It proves efficient to support the scale up of SAF. It aims to de-risk investments by providing certainty about the mandated amounts. It is also easier to implement as supplied amounts can be measured and thus easily verified. On the contrary, emissions savings can only be estimated based on a complex life cycle assessment usually conducted by the fuel producer. The sub-mandate concept can be justified wishing to incentivise a high potential, but less commercially mature SAF to deliver future climate benefits.

iii. CO_2 intensity reduction-based approach.

A CO_2 intensity reduction-based obligation focuses on the CO_2 intensity reduction rather than just volume and is generally recognised as technology-neutral because it does not impose the scaling up of certain technologies to determined levels, but lets the market react based on the CO_2 performance of each technology.

SAF can count towards meeting the target to the extent of the CO_2 intensity reduction they achieve. A multiplier is a lighter form of support, compared to a sub-mandate. It provides less certainty that innovative types of fuel are developed at commercial scale. Claims about achieved CO_2 emission reduction may also be more difficult to verify. The value of this multiplier decreases over time, as the cost efficiency of a newer specific fuel (e.g. PtL) improves.

Appendix C - Policy Approach Example: UK Jet Zero Consultation

UK Jet Zero consultation provides an example of a SAF policy making process and is outlined below. UK policy definition of SAF is potentially a good guide for others.

What are SAF?

“SAF” are low carbon alternatives to conventional, fossil derived, aviation fuel – ‘drop in equivalents’ that present similar characteristics to conventional jet fuel. Generally, SAF can be produced from three types of feedstock:

• Biomass: this includes biogenic waste, e.g. used cooking oil. • Non-biogenic waste: e.g. unrecyclable plastics or waste fossil gases from industry.

• CO_2 + green hydrogen: zero-carbon electricity is used to produce hydrogen through water electrolysis; hydrogen then reacts with CO2 captured from the air or waste industrial exhaust streams to produce a synthetic fuel. This process is known as Power-to-liquid (PtL).

UK Existing policy commitments:

- We will shortly consult on a UK SAF mandate setting out our level of ambition for future SAF uptake and defining the scope, technology, compliance and reporting implications underpinned by it.

- We have formed the Clean Skies for Tomorrow SAF Ambassadors group, which will develop, pilot and promote industry-led policy proposals for national SAF policies, ahead of COP26.

- We will continue to engage SAF stakeholders through the Jet Zero Council SAF Delivery Group, to ensure future SAF policy is robust.

- We have consulted on the possibility of expanding the RTFO to reward recycled carbon fuels (RCF) which are produced from fossil wastes that cannot be avoided, reused or recycled.

- We are supporting the development of SAF through the Green Fuel, Green Skies competition, through which companies will be able to bid for a share of £15 million in 2021-22 to kickstart the development of first-of-a-kind production plants in the UK. Successful projects are expected to be announced in summer 2021.

- We will establish a SAF clearing house to enable early stage aviation fuel testing as an essential capability to support our decarbonisation agenda.

UK SAF Mandate consultation:

The UK SAF mandate consultation contains some useful guidance on the key areas a policy maker should consider before developing and implementing a SAF policy.

Key principles of the UK SAF mandate proposal:

- Introduction of a bespoke SAF mandate, separate from the RTFO
- GHG emissions scheme whereby credits are awarded proportional to the amount of CO_2e saved
- Tradeable credit scheme
- Obligation to fall on suppliers of jet fuel to the UK
- Whether the obligation should apply to all avtur, regardless of whether it is subject to fuel duty or not

- If a threshold should be introduced below which fuel is not obligated
- Where the assessment point should fall for fuel not subject to fuel duty

Fuel eligibility and sustainability criteria

- SAF supplied in the UK should meet DEF STAN 91-091 specification
- Only SAF from waste-derived biofuels, RFNBOs, SAF from nuclear origin and RCFs can contribute to the obligation
- Land use criteria to be applied to forestry residues
- Where hydrogen is used as a feedstock (i.e. contributes to final fuel energy content), it must be low carbon hydrogen

Carbon savings

- Baseline lifecycle GHG emissions intensity of 89 gCO_2e/MJ
- What the minimum carbon intensity reduction of SAF should be
- Whether there are land use or other implications to be accounted for
- Whether the minimum carbon intensity reduction should be reduced going forward in line with the development of CCUS
- What the GHG methodology should be and how it should account for different
- fuels, feedstocks, and pathways
- SAF that does not meet the criteria will incur an obligation

Overarching trajectory

- Mandate to start in 2025
- Targets to assume a linear growth up to 2035 and exponential growth after 2035
- What level of ambition presents the correct trade-off between ambition and deliverability
- Introduce review points in 2030, 2035, and 2040
- Whether the amount of HEFA should be capped
- How to incentivise PtL and other pathways

Interactions with other policy

- SAF GHG emissions to be claimed only once under different schemes
- How UK ETS, CORSIA and SAF mandate could be used together to incentivise uptake but avoid double counting
- SAF produced from plants that have received competition funding to be claimed under mandate
- SAF no longer allowed to be rewarded under the RTFO
- Provisions to reduce tankering

Policy framework

- Whether a policy framework is needed and how it could be designed
- Whether a buy out should be allowed and how it could be set
- If any other penalties should be set

Scheme practicalities, reporting and verification

- Mass balance approach to be the only chain of custody permitted
- Where the chain of custody should end
- Obligated suppliers to report annually to DfT, regardless of whether they claim SAF credits
- The information of reporting and reporting calendar
- Timescale for submitting claims
- Evidence of compliance
- Claims for credits should be verified either to a limited or reasonable assurance

Appendix D - Policy Approach Example: United States SAF Grand Challenge

The United States 2021 Aviation Climate Action Plan was announced on November 9, 2021. It provides an example of an overarching policy framework to achieve the U.S. Aviation Climate Goal of "*Net-Zero GHG Emissions from the U.S. Aviation Sector by 2050*." Within this framework the Action Plan states that SAF will be critical to the long-term decarbonization of aviation. It commits the U.S. government to work with industry to rapidly scale up SAF production with the goal of meeting the fuel needs of U.S. aviation by 2050 through a range of policy instruments, including the "SAF Grand Challenge" – a broad framework for expanding SAF.

The approach emphasizes the role of U.S. executive branch authorities and programs to support research, development, demonstration, deployment, and commercialization of SAF. In addition to actions taken by executive branch agencies, the plan recognizes the need for well-designed economic incentives that could be legislated by the U.S. Congress, including blender's tax credits and investment tax credits, to help bridge the cost gap between SAF and petroleum jet fuel.

SAF Grand Challenge:

The SAF Grand Challenge is defined as a multi-agency initiative led by the U.S. Department of Transportation (DOT), Department of Energy (DOE), and Department of Agriculture (USDA) to implement a government wide effort to reduce cost, enhance sustainability, and expand production and use of SAF. It was announced at a White House Roundtable on Sustainable aviation on September 9, 2021.

Goals:

Scaling up U.S. SAF production to at least 3 billion gallons of SAF per year by 2030 and, by 2050, sufficient SAF to meet 100% of aviation fuel demand, which is currently projected to be around 35 billion gallons per year.

Definition of SAF:

- "drop-in" liquid hydrocarbon fuels with the same performance and safety as conventional jet fuels produced from petroleum
- fully fungible with the existing fuel supply and can be used in today's infrastructure, engines, and aircraft
- can be created from either renewable or waste materials
- reduce life cycle GHG emissions by at least 50% relative to conventional jet fuel

The use of some SAF types will reduce emissions that degrade air quality and could reduce the contribution of contrails to climate change.

Intent:

Through the SAF Grand Challenge, DOE, DOT, and USDA, will work with other agency partners to enable an ambitious government-wide commitment to: 1) leverage existing government activities in research, development, demonstration, deployment, commercialization support, and policy; 2) accelerate new research, development, demonstration, and deployment support; and, 3) implement a supporting policy framework. To meet the Goals of the Grand challenge these actions are intended to:

- **Reduce the cost of SAF** through critical activities that drive down cost of production across the supply chain; expand the feedstock and conversion technology portfolio; leverage and repurpose existing production infrastructure; reduce risk to industry; and provide incentives for production.
- **Enhance sustainability of SAF** by maximizing the environmental co-benefits of production; demonstrating sustainable production systems; developing low land-use change feedstock crops;

reducing the carbon intensity of SAF supply chains; ensuring robust standards that guarantee environmental integrity through rigorous life cycle analysis; and, enabling approvals of higher blend levels of SAF.

- **Expand SAF supply and end use** through support for regional feedstock and fuel production development and demonstration; outreach, extension, and workforce development; new infrastructure and commercialization support through federal programs; implementation of supporting policies that are enacted for SAF; enabling approvals of diverse SAF pathways; and, continued outreach and coordination with military and industry end users.

Summary of Actions on SAF:

- Continue to support critical U.S. government programs on research, development, demonstration, and deployment of feedstock systems, conversion, testing, analysis, and coordination on SAF directly with industry and through the Commercial Aviation Alternative Fuels Initiative (CAAFI).
- Develop a multi-agency roadmap within the next year to identify agency roles and an implementation plan
- Leverage existing USG activities in research, development, demonstration, deployment, commercialization support, and policy
- Accelerate additional research, development, demonstration, and deployment (RDD&D) needed for innovative solutions and technologies
- Catalyze bulk purchases of SAF by military and other end users
- Implement a supporting policy framework, including enactment of proposed Sustainable Aviation Fuel tax credit proposed in the Build Back Better Agenda to help cut costs and rapidly scale domestic production of SAF

— END —