Clean Skies for Tomorrow

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WORLD ECONOMIC FORUM

In Collaboration with
the Energy Transitions
Commission

Clean Skies for Tomorrow: Sustainable Aviation Fuel Policy Toolkit

INSIGHT REPORT

NOVEMBER 2021

Images: Getty Images

Contents

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Foreword by ministers

“Kenya supports a low-carbon, climate resilient development pathway in order to contribute to the Paris Agreement through the Clean Skies for Tomorrow Sustainable Aviation Fuel Policy Toolkit. This will include the promotion and implementation of clean, efficient and sustainable energy technologies to reduce overreliance on fossil and non-sustainable biomass fuels to achieve net zero in the aviation sector for society and the planet.

KENYA
James W. Macharia, Cabinet Secretary for Transport, Infrastructure, Housing and Urban Development and Public Works of Kenya

“Showcasing our strong commitment to addressing the challenges of climate change with our global partners, the Netherlands is proud to be an ambassador of the Clean Skies for Tomorrow Sustainable Aviation Fuel (SAF) Policy Toolkit. In pursuing a sustainable future for our children, we have the obligation to meet the climate goals in the Paris Agreement. For this, the aviation sector – like any other sector – needs to decarbonize. SAF represent a key element in the reduction of greenhouse gas emissions while safeguarding the important role of the aviation sector in maintaining the advantages of a connected world. To efficiently realize the potential of SAF at scale, sustainable international markets and long-term policy strategies need to be developed. This SAF Policy Toolkit will inspire and support policy-makers worldwide in working together to achieve successful SAF deployment, building a zero-emissions aviation sector.

NETHERLANDS
Barbara Visser, Minister of Infrastructure and Water Management of the Netherlands

“Singapore is delighted to be part of the World Economic Forum Clean Skies for Tomorrow Sustainable Aviation Fuel (SAF) Ambassador group. As air travel recovers from the COVID-19 pandemic, the aviation sector we rebuild must be a more sustainable one. SAF is one critical enabler in the sector’s decarbonization effort. We hope this toolkit can help governments and industry collaborate on policy, technology and operational development, and accelerate SAF supply and use.

SINGAPORE
S. Iswaran, Minister for Transport and Minister-in-charge of Trade Relations of Singapore

“The Government of the United Arab Emirates believes in the importance of sustainable energy, investing in the future and strengthening international collaboration to address the challenge of climate change in all sectors, including aviation. Experts from the United Arab Emirates therefore have engaged positively in international, regional and national efforts to achieve reductions in emissions from international civil aviation. The United Arab Emirates supports the Clean Skies for Tomorrow initiative to develop a policy toolkit as an aid for states to select and implement policies and strategies for sustainable and low-carbon aviation fuel. From this toolkit, states will be able to select policies that best suit their national strategies to promote the development and uptake of these fuels, which will be a necessary enabler for the aviation sector to achieve its emissions reduction goals.

UNITED ARAB EMIRATES
Suhail Al Mazrouei, Minister of Energy and Infrastructure of the United Arab Emirates; Chairman, Low Carbon Aviation Fuel and Sustainable Aviation Fuel Committee

“It has been a pleasure working with my fellow Ambassadors, the World Economic Forum and with the support of the Energy Transitions Commission to develop the Clean Skies for Tomorrow Sustainable Aviation Fuel Policy Toolkit. Sustainable aviation fuels represent one of the most promising measures for reducing the climate impact of flying. Tools like this support our journey in accelerating the deployment of sustainable aviation fuels, which is critically important. We know this journey will not be easy but we are determined to realize the benefits of a thriving, net-zero aviation sector for society, the economy and the planet. We welcome countries worldwide, at all stages of sustainable aviation fuel policy and industry development, to engage with and use the toolkit.

UNITED KINGDOM
Robert Courts, Minister for Aviation, Maritime and Security of the United Kingdom

The Clean Skies for Tomorrow initiative would also like to thank the participating SAF Ambassador Government of Costa Rica, through Andrea Meza, Minister of Environment and Energy, for its contributions to the development of this policy toolkit.

Preface

The Sustainable Aviation Fuel (SAF) Policy Toolkit aims to support governments and policy-makers as they develop and implement national SAF strategies.

The World Economic Forum's Clean Skies for Tomorrow (CST) initiative created this *Sustainable Aviation Fuel Policy Toolkit* in collaboration with member governments in the CST Sustainable Aviation Fuel (SAF) Ambassadors group, with the support of the Mission Possible Partnership. It is intended to serve as an indicative "menu of options" for policy-makers worldwide to support the scaling of sustainable SAF markets across regions.

CST's SAF Ambassadors group is a geographically, demographically and economically diverse group of governments chaired by the United Kingdom, given the country's role as President of the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) in Glasgow in 2021. Each member government shares a commitment to addressing the climate crisis and decarbonizing aviation while retaining the benefits of global connectivity that the sector provides. The creation of this report would not have been possible without their significant contributions.

While all stakeholders have a role to play in the upscaling of SAF, this toolkit focuses on the role of governments and policy-makers in removing barriers and facilitating increased supply and demand. It is also purposely designed with reference to the diversity of national contexts and varying stages of sectoral decarbonization by providing examples and analysis that are useful regardless of status.

This report contains three key sections:

1. An **Introduction** addressing key points for policy-makers, including the need for national-level policy support and the role of international cooperation
2. **SAF strategy guidance** addressing critical actions before pursuing specific policies
3. A **Toolkit of policy options** providing a decision pathway for policy-makers; policies are presented under three subsections: Supply, Demand and Enablers.

Importantly, the strategy advice, policies and accompanying analysis are provided as a thought exercise; no singular government or group of governments endorses them. As with any government policy, analysis must be conducted on a country-by-country basis considering the best solutions for contextually specific needs. Moreover, SAF is a complex research subject with potential large-scale implications for any economy. Policy-makers should use this toolkit to complement their own independent research and decision-making process.

Clean Skies for Tomorrow

The Clean Skies for Tomorrow initiative provides a crucial global mechanism for top executives and public leaders to align on a transition to sustainable aviation fuels as part of a meaningful and proactive pathway for the industry to achieve carbon-neutral flying. The World Economic Forum leads the Clean Skies for Tomorrow initiative in collaboration with the Rocky Mountain Institute and the Energy Transitions Commission.

Mission Possible Partnership

The Mission Possible Partnership (MPP) is an alliance of climate leaders focused on supercharging efforts to decarbonize some of the world's highest emitting industries in the next 10 years. MPP comprises four core partners – the Energy Transitions Commission, RMI, the We Mean Business Coalition, and the World Economic Forum.

Introduction

Sustainable aviation fuel (SAF) will continue to play a key role in aviation decarbonization between now and 2050.

The role of sustainable aviation fuels in a climate-change constrained world

To meet broad-ranging mid-century climate goals, it will be necessary to put key measures in place globally to reduce greenhouse gas (GHG) emissions. For the aviation sector, achieving net-zero emissions by 2050, a target that industry and governments are increasingly aligning with, will require careful planning and decisive action by all stakeholders.

There is no silver bullet and success will come from a combination of new technologies and processes. Most technical projections forecast a number of different solutions across the sector by 2050, with shorter flights increasingly reliant on the development of electric and hydrogen technologies. Sustainable aviation fuels (SAF) will continue to be indispensable through at least the medium term, especially for medium- and long-haul flights, which together account for the bulk of CO_2 emissions from aviation.

FIGURE 1 **Indicative profile of aviation decarbonization technology deployment**

	2020	2025	2030	2035	2040	2045	2050
Commuter • 9-19 seats • <60 min. flights • <1% of industry CO_2	SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF
Regional • 50-100 seats • 30-90 min. flights • ~3% of industry CO_2	SAF	SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF
Short-haul • 100-150 seats • 45-120 min. flights • ~24% of industry CO_2	SAF	SAF	SAF	SAF, potentially some hydrogen	Hydrogen and/or SAF	Hydrogen and/or SAF	Hydrogen and/or SAF
Medium-haul • 100-250 seats • 60-150 min. flights • ~43% of industry CO_2	SAF	SAF	SAF	SAF	SAF, potentially some hydrogen	SAF, potentially some hydrogen	SAF, potentially some hydrogen
Long-haul • 250+ seats • 150+ min. flights • ~30% of industry CO_2	SAF	SAF	SAF	SAF	SAF	SAF	SAF

Source: Air Transport Action Group, *Waypoint 2050*, 2021[1]

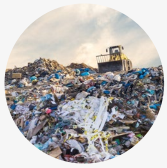
How is SAF defined?

SAF describes non-conventional (fossil-derived) aviation fuel produced from biological (plant or animal material) and non-biological sources (e.g. municipal waste or waste CO_2). Sustainable aviation fuel is typically produced in a purpose-built plant rather than a fossil fuel refinery, using a range of technology pathways and feedstocks.[2]

There are currently four key SAF production pathways, with others too nascent or not yet approved by ASTM (an international standards organization) to enable immediate application.

FIGURE 2 **Key SAF production pathways**






	HEFA	Alcohol-to-jet[i] / Gasification/FT	Power-to-liquid
Opportunity description	Safe, proven, and scalable technology	Potential in the mid-term, however, significant techno-economic uncertainty	Proof of concept 2025+, primarily where cheap high-volume electricity is available
Technology maturity	Mature	Commercial pilot	In development
Feedstock	Waste and residue lipids, purposely grown oil energy plants[ii] Transportable and with existing supply chains Potential to cover 5%-10% of total jet fuel demand	Agricultural and forestry residues, municipal solid waste,[iv] purposely grown cellulosic energy crops[v] High availability of cheap feedstock, but fragmented collection	CO_2 and green electricity Unlimited potential via direct air capture Point source capture as bridging technology
% LCA GHG reduction vs. fossil jet	73%–84%[iii]	85%-94%[vi]	99%[vii]

i. Ethanol route; **ii**. Oilseed bearing trees on low-ILUC (indirect land use change) degraded land or as rotational oil cover crops; **iii**. Excluding all edible oil crops; **iv**. Mainly used for gas./FT; **v**. As rotational cover crops; **vi**. Excluding all edible sugars; **vii**. Up to 100% with a fully decarbonized supply chain

Source: World Economic Forum, *Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation*, 2021

SAF advantages

Compared to conventional jet fuel, SAF can offer up to a 100% reduction in CO_2 emissions on a life-cycle basis, depending on the feedstock and production technology used.[3] There is also emerging evidence that SAF can contribute to decreases in radiative forcing and improvements in local air quality.[4] Importantly, SAF is available today as a drop-in solution, compatible with existing aircraft systems and airport infrastructure, providing a significant practical and financial advantage compared to other decarbonization options, and is currently rated as usable in all aircraft up to a 50% blend.[5] Beyond this, SAF provides social and economic opportunities and supports energy security diversification efforts.[6]

Existing cooperation

In 2016, the International Civil Aviation Organization (ICAO) and its member states agreed to the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), with the aim of carbon-neutral growth from 2021. At the time, this marked significant progress, with aviation the first transport sector to voluntarily establish a pathway to decarbonization. Since then, the airlines and wider industry,[7] as well as many individual players in the aviation value chain, have committed to net-zero carbon emissions or carbon neutrality by 2050.[8]

While CORSIA represents an enormous level of cooperation and progressive ambition, it remains a compromise that, when implemented, will result in outcomes short of those necessary to achieve decarbonization. SAF remains a critical element in attaining sectoral climate goals. Yet, while CORSIA allows airlines to reduce their offsetting obligations using SAF, more comprehensive policy action will be required to drive substantial changes in SAF use.

As at mid-2021, airlines have operated more than 365,000 commercial flights using SAF and future purchase agreements total over $7 billion.

At national and regional levels, government initiatives are already under way. The US Government has announced actions to reduce aviation emissions by 20% by 2030 and Congress has introduced legislation to establish a blender's tax credit for SAF.[9] In the European Union, the European Green Deal is aiming for a climate-neutral economy by 2050 and, through its ReFuelEU aviation proposal, is considering a SAF blending mandate.[10] The United Kingdom also recently released their net-zero strategy, including significant commitments to increasing national use of SAF.[11] Many other countries are currently in discussions over policies and regulations that would achieve similar outcomes.

Various pilot projects and first-of-a-kind SAF plants have demonstrated that SAF production and delivery is possible. As at mid-2021, airlines have operated more than 365,000 commercial flights using SAF and future purchase agreements total over $7 billion.[12]

However, despite this progress, there needs to be an unprecedented and immediate global ramping up and adoption of SAF. This will require strong political support, breakthrough technical innovation, significant financial investments, and robust long-term public policies.

Major challenges to scaled SAF deployment

SAF is physically and chemically similar to jet fuel, resulting in categorization of many SAF types as "drop-in fuel". Despite this advantage, SAF production volumes remain low and account for less than 1% of global jet fuel consumption.[13] A combination of techno-economic factors has been halting further progress.

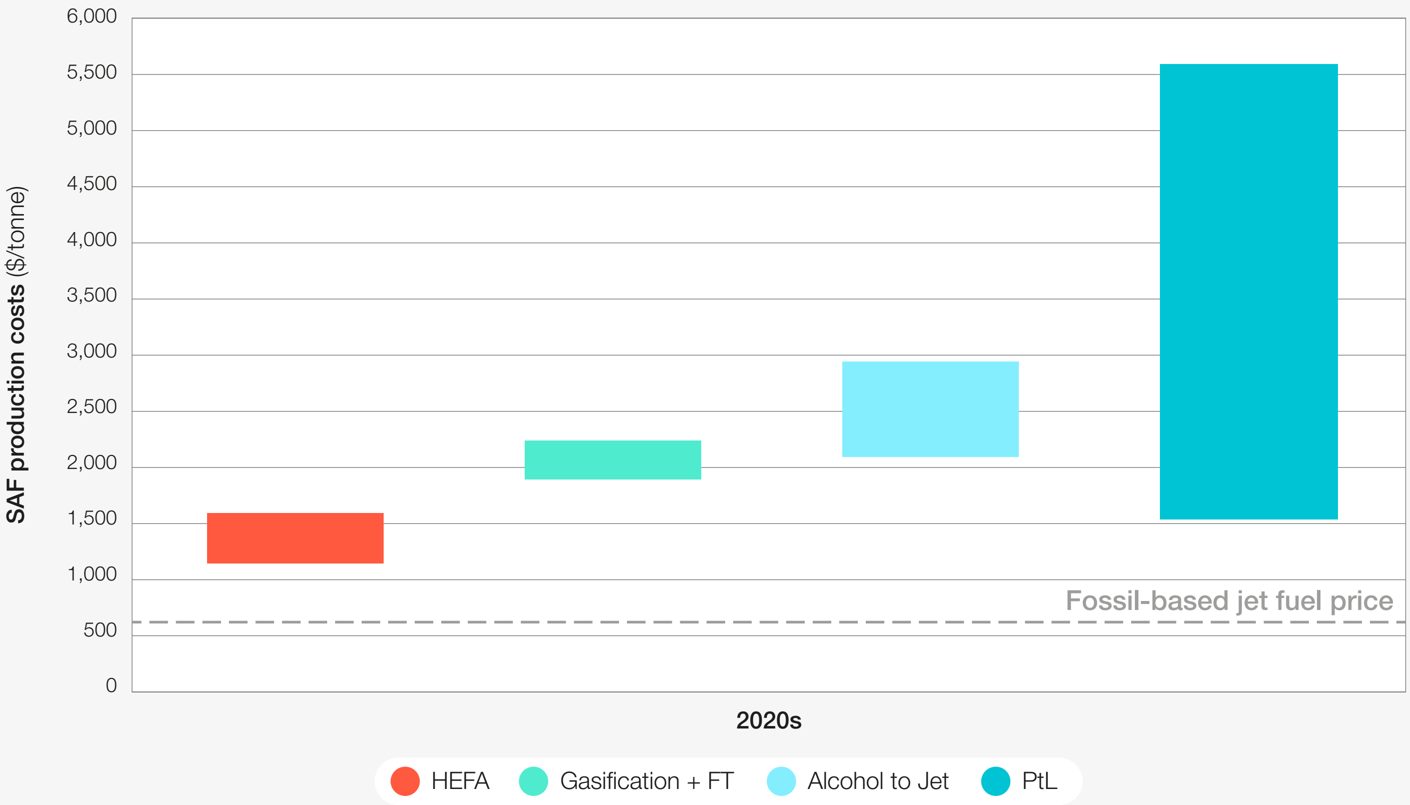
Cost differential

Currently, the largest barrier to wider SAF use is cost. SAF production expenses result in market prices 2-4 times greater or more than traditional fossil jet fuel, depending on the production pathway used, limiting the potential for market-driven scale-up. Regulation and fiscal policies will be required to help bridge this cost differential, drive demand, and generate greater certainty for investors and financers.

Technological readiness

Theoretically, there is sufficient feedstock globally to power all of aviation by 2030; however, it is necessary to make improvements in feedstock production and collection and in technology allowing for the use of a broad range of feedstock types.[14] New scalable production routes include alcohol-to-jet (AtJ), gasification/Fischer-Tropsch (G/FT), and power-to-liquid (PtL). Critical investments in research, development and demonstration (RD&D) are needed to see these technologies and production pathways mature.

FIGURE 3 **Indicative SAF costs by production pathway**



Source: World Economic Forum, *Clean Skies for Tomorrow: Sustainable Aviation Fuel as a Pathway to Net-Zero Aviation*, 2021
Note: Lower range for PtL in regions with cheaper renewable power

> Without clear SAF targets and direction for aviation, other sectors remain a more attractive option for producers and investors.

Sectoral allocation
Aviation is not the only transport sector that must decarbonize but it is one of the more difficult to abate. Currently, the road sector uses the majority of renewable fuels. Higher production costs associated with SAF output and more limited demand uptake are disincentives for producers to redirect feedstock to aviation. In many states there is often little inter-sectoral coordination, which compounds the challenge.

Investment
The transition to SAF requires major investment. It may be necessary to build or remodel entire processing facilities and develop entire supply chains. In Europe alone, experts expect investments in new SAF plants to be in the order of €15 billion/year on average until 2050.[15] Attracting this investment requires sufficient certainty of future demand and de-risking of the first wave of projects. Without clear SAF targets and direction for aviation, other sectors remain a more attractive option for producers and investors.

Level playing field
In the absence of a global mandate or agreed decarbonization pathway, progress is most likely at the national or regional level with limited coordinated efforts. Such an approach is of concern for industry and civil society alike, as an ad-hoc implementation approach and inherent inefficiencies to implementation could lead to a breakdown in overall effectiveness through issues like competitive distortion or carbon leakage, as well as complicated and time-consuming monitoring and reporting requirements.

The need for policy intervention

Most countries have adopted some form of renewable energy policy at the national level,[16] scaling industry's development, investment and environmental benefits in recent years.[17] In particular, public policy has played a pivotal role in scaling renewable energy markets such as wind and solar and developing biofuels for road transport. The same is now needed for SAF.

Accelerating the pace of aviation decarbonization will require a coherent set of policy interventions that rapidly strengthen the business case for private investment, bridge the price differential, and stimulate SAF demand. Failure to achieve this will be detrimental for society and the entire aviation value chain as slower emissions reductions today will necessitate a faster and higher cost of transition in the future.

The SAF Ambassadors initiative has identified five key areas where policy interventions can have the most impact. The section on Policy options to support the development of a scaled SAF market explores these further: ensuring feedstock sustainability, stimulating its production and redirecting its use for SAF; supporting RD&D to bring new SAF pathways to market; de-risking private investments to increase SAF production capacity; stimulating voluntary, mandatory, and market-based SAF demand; and easing SAF trading barriers to support a global level-playing field.

Domestic and international policies are both necessary
A joint global solution would be optimal to increase SAF uptake; but reaching international consensus on the best way forward will take time, particularly as states vary in their political and technological readiness to create and participate in SAF markets.

Importantly, domestic and international aviation fall under different jurisdictions. Domestic aviation normally comes under national laws, while the International Civil Aviation Organization (ICAO) oversees international aviation. Even with a robust international system in place, a coherent national policy aligned with international direction where possible will play an important role in developing the SAF market.[18]

The broader value chain is also a significant contextual component. National policy will be required to incentivize the production of sustainable bio and non-bio feedstocks, build up national supply chains, and ensure that enough sustainable feedstock is allocated to SAF production.

The value of global standardization

Wherever possible, national policies should seek to align with international and regional sustainability standards. This will support both the longer term goal of a robust international SAF market and will also facilitate efficient international trade and effective emissions accounting in the short term. The lack of policy and regulatory harmonization often leads to a patchwork of systems and requirements that results in carbon leakage, missed technological and feedstock opportunities, and underinvestment due to concerns about market stability.

Policy-makers are encouraged to participate in ongoing dialogue at the ICAO level to ensure that global regulations and standards take into consideration regional and national contexts.

1 Considerations for creating a SAF strategy

Before implementing SAF policies, states should first develop a coherent national SAF strategy. The following considerations may help inform policy direction.

Gathering intelligence and establishing a fact base

Due to the complexities of SAF feedstock and aviation sector operations, each region and market will need to develop its own fact base and analysis. From context-specific financial models to feedstock availability and renewable energy sourcing, it is essential for policy development to be uniquely adapted to its environment. The SAF Ambassadors group supports the use of industry best practices and "smarter regulation" guidance, such as that provided by the Organisation for Economic Co-operation and Development (OECD) and the International Air Transport Association (IATA), to build economically viable and environmentally sustainable SAF-supportive policy.

Such intelligence gathering, research and analysis forms a key pillar of CST's overarching project implementation, especially for in-depth, holistic market studies, such as its ongoing work in India and in other emerging markets. In producing the in-depth CST India study and informing its translation into a government-led task force, CST ran a comprehensive analysis of feedstock availability and sustainability, SAF production capacity and feasibility, technological maturity, as well as expected social and economic benefits and the establishing of an expected return on investment (ROI) for public-sector investment.[19] This analysis provided a critical contextual argument on which the government is designing appropriate supportive policy measures.

As an example outside of CST, the Government of Singapore conducted a study of the operational and commercial viability of SAF at Changi Airport alongside industry engagement. The study presents various options to integrate SAF along the supply chain inclusive of relevant operational contexts.[20]

Similarly, ICAO, with the support of the European Union, conducted a series of SAF feasibility studies in selected states in the Caribbean and Africa (Kenya[21] and Burkina Faso[22]) to understand their potential capacity and propose roadmaps to develop local supply chains.[23] These studies continue to inform the policy constructs within those specific markets as well as more broader policy design, including those considered here by the CST SAF Ambassadors group.

> Governments should work closely with the private sector and international partners to ensure that national SAF goals maintain high levels of ambition while limiting regional market distortions.

Setting a vision

Governments can influence market expectations by setting ambitious targets for national SAF production and consumption. Commitments – and the policies that deliver on them – should be long term, reflecting the timeframes for investment. Governments should work closely with the private sector and international partners to ensure that national SAF goals maintain high levels of ambition while limiting regional market distortions.

After commissioning a study on the potential effectiveness of renewable energy obligations for aviation,[24] the Dutch Government has committed to ensuring that 14% of aviation fuel in the Netherlands must be sustainable by 2030 and all aviation fuel must be SAF by 2050.[25]

Creating a transition pathway

To achieve a SAF vision in an orchestrated way, nations should develop a transition strategy that informs decision-makers about the nature, timing, cost and scale of actions needed. Such a strategy should consider short and long-term goals, suitable technological pathways according to a country's feedstock availability, regulatory mechanisms that need to be created or adapted, required infrastructure build-out, the role of national agencies, ways to build social awareness and legitimacy for SAF, and the scale of the public funds needed to deliver the strategy. Additional guiding principles, meaning the key factors a state might view as important to achieving the vision – such as taking a partnership-based approach or guaranteeing SAF must deliver GHG emissions reductions above a minimum threshold – may underpin it.

Flexible and inclusive policy

States will also need to consider whether their vision and transition strategy should be sector-specific or whether aviation will form a part of a broader national strategy. As a minimum, an aviation strategy should align with other sectoral strategies to ensure no domestic market distortion or unnecessary competition for resources arises. Further, broader sectoral strategies would do well to include focused guidance on SAF, in particular due to its complexity, as vague energy or renewable fuel incentive frameworks may not adequately address its unique set of challenges.[26]

Managing risk

States should explore ways to identify and mitigate the associated risks deriving from their SAF strategy, including whether it delivers genuine carbon savings or leads to unintended outcomes, such as competitive distortions that could financially hurt national carriers or pose a significant burden on public budgets that could discontinue supporting policies.

National, regional and international cooperation

It takes the entire value chain to create a SAF market at scale. Extensive multilateral and peer-to-peer interaction between governments, industry, consumers and NGOs will be needed to accelerate SAF deployment. Collaboration can range from aligning best practices on sustainability standards to considering how to best close the price gap between SAF and conventional jet fuel.

The Jet Zero Council, for example, is a partnership between industry and the Government of the United Kingdom with a focus on developing SAF production facilities in the country and coordinating the approach to the regulatory frameworks needed for a net-zero industry by 2050.[27]

Beyond national partnership development, it is crucial for states to continue participating in regional and international dialogue such that national, regional and international policies and SAF strategies align where possible. Given aviation's inherently international status, this approach can accelerate SAF adoption while mitigating carbon leakage risks and competitive distortions.

2

Policy options to support the development of a scaled SAF market

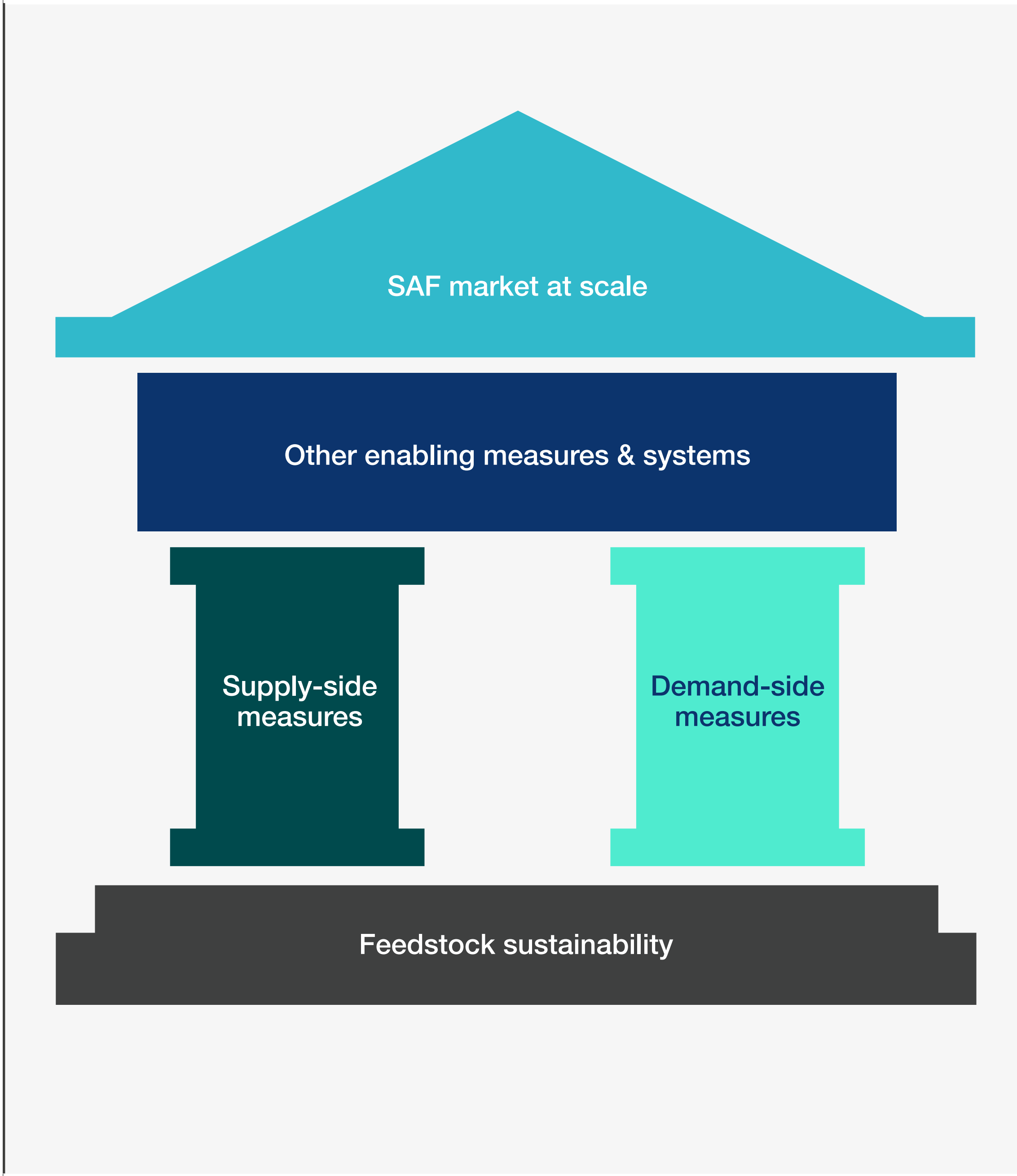
Policy-makers will need to consider the most appropriate combination of policy options to address their unique national needs.

The need for long-term policy frameworks for SAF uptake is clear. The most suitable policies, however, are likely to vary for each country according to their geographic, economic, social and political characteristics. Nations that already possess a mature renewable fuel industry and comprehensive carbon emissions legislation might choose different policy levers from those looking to take their first SAF steps.

Regardless, no individual policy will drive SAF growth on its own. A range of supply, demand and enabling policy instruments aligned to each country's circumstances in terms of feedstock availability, value chain maturity, energy dependency, and climate goals need to be planned and implemented in a coordinated way. It is necessary to seek a balance between supply and demand policies to preserve market equilibrium and avoid possible carbon leakage.

This section highlights several policy mechanisms and examples that could be used to support SAF production and use, following a structured framework paradigm detailed in *Figure 4*. All policies featured in this section are for reference only and should be considered only within localized context and selected following rigorous analysis by policy-makers. Additionally, the examples are presented only for policy implementation reference and without judgement or endorsement as a success or failure.

FIGURE 4 **Overview of regulatory framework for a SAF market at scale**



Source: Agora Energiewende, *Making renewable hydrogen cost-competitive: Policy instruments for supporting green H_2*, 2021

2.1 SAF feedstock sustainability

For SAF to function as a sustainable alternative to fossil fuels, it must be produced from sustainable feedstocks that significantly reduce GHG emissions on a full life-cycle basis. A set of policies that ignores this principle risks both nullifying the positive environmental effects expected from producing SAF and economically undermining the value chain built for it.

The tight sustainability criteria for SAF anchors the analysis from the CST initiative, using as a baseline an overall life-cycle emissions reduction of 60% vs conventional fuels, in line with guidelines established by the Roundtable on Sustainable Biofuels (RSB).[28] Other CST guiding principles are outlined below as a quick-reference guide for policy-makers.

Ensuring feedstock is sustainably sourced

Supporting global SAF production requires a range of feedstocks as no single feedstock can sufficiently meet every need. Environmental integrity and supply chain verification, however, are crucial to selecting the suitable feedstocks as SAF must not threaten food security, result in direct or indirect land-use changes, or have significant emissions footprints from production.[29]

Feedstocks for each of the four SAF production pathways that are most likely to scale (as previously detailed in Figure 2) vary across biologic and non-biologic types and have different levels of life-cycle GHG emissions reductions and a different sustainability risk profile.[30] These complex combinations of technologies and feedstock sourcing could potentially lead to SAF with no net emissions benefits or even emissions greater than conventional jet fuel, necessitating rigorous sustainability requirements, monitoring and evaluation.

In the short term, as the industry scales, policy frameworks will need to pragmatically balance feedstock availability and sustainability and build in flexibility to adapt as technology and feedstock supply evolve.

FIGURE 5 **Overview of potential feedstocks for the production of SAFs**

All feedstock must fulfil sustainability criteria

Feedstock type	Feedstock category			Feedstock[vi]	Substantial GHG savings potential[vii]	Low sustainability concerns[viii]
1st gen / crop-based	Edible oil crops			Palm	✗	✗
				Soybean	✗	✗
				Other (incl. sunflower, rapeseed/canola)	✗	✗
	Edible sugars			Sugar cane	(✓)	✗
				Maize	✗	✗
				Other	✗	✗
Advanced and waste	Waste and residue lipids[ii]			Used cooking oil (industrial or private sources)	✓	✓
				Animal waste fat (tallow)	✓	(✓)
				Other (incl. tall oil, technical corn oil, fish oil, POME, PFAD)	✓	(✓)
	Purposely grown energy plants	Oil trees on degraded land		Jatropha, pongamia	✓	(✓)
		Rotational cover crops	Oil cover crops	Camelina, carinata, pennycress	✓	(✓)
			Cellulosic cover crops	Miscanthus, switchgrass, reed cannarygrass	✓	(✓)
	Agricultural residues			Rice straw	✓	✓
				Sugar cane bagasse	✓	✓
				Other (incl. corn stover, cereal residues)	✓	✓
	Forestry residues[iii]				✓	✓
	Wood-processing waste[iv]				✓	✓
	Municipal solid waste[v]				✓	✓
Recycled carbon	Reusable plastic waste				✗	✓
	Industrial waste gas	CO_2 from point source capture (CCS)			✓	✓
		Other (e.g. flue gas from steel production)			✓	✓
Non-biomass based[i]	CO_2 from direct air capture (DAC)				✓	✓

| Focus of analysis (Advanced and waste; Recycled carbon / Non-biomass based) ✓ Satisfied (✓) Potentially satisfied[ix] ✗ Not satisfied

i. Adjustment of RED II category "Renewable fuel of non-biological origin"; **ii**. Some not included in RED II definition of advanced (e.g., used cooking oil, animal waste fat), while others are (e.g., tall oil, POME); **iii**. Leftovers from logging operations, including leaves, lops, tops, damaged or unwanted stem wood; **iv**. By-products and co-products of industrial wood-processing operations, including sawmill slabs, saw dust, wood chip; **v**. May contain up to 20% non-reusable plastics; typically inefficient to separate organics and plastic; **vi**. Algae not assessed due to limited feasibility; **vii**. In line with RSB: >60% based on LCA,; **viii**. Mainly related to food security and land use change; **ix**. Depending on local circumstances

Source: World Economic Forum, *Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation*, 2021

Managing the allocation of renewable feedstock
Policy-makers will need to manage renewable feedstock allocation between sectors, especially in the short-term, when demand is likely to exceed supply.[31] National inter-sector coordination will likely be required to prioritize resources across the whole economy, focusing on ensuring that allocation is based on each sector's carbon intensity and on cost and availability of alternative decarbonization technologies. Hardest to abate sectors, such as aviation, should be given special consideration. Care must be taken, however, to use a systems-thinking approach so as to avoid creating spill-over effects causing other environmental harms by deprioritizing other sectors.

Financial mechanisms to bridge the cost differential and ensure that SAF production is financially attractive will also be required to see producers optimize their product slate for SAF.

Pace of transition to prioritized use
In order not to disrupt current markets, the pace at which it is necessary to redirect feedstocks for aviation will be linked to the pace at which non-bio decarbonization solutions become accessible in other sectors and on the balance between feedstock availability and demand for a given country. The faster governments manage to electrify other sectors via renewable electricity, the faster they will be able to free up feedstock and divert production capacity for SAF.

Ultimately the availability of SAF will depend on:

– Availability of agricultural biomass from no or limited direct or indirect land-use change sources

– Availability of feedstocks from waste oils and fats, enhanced through policy incentives for waste collection

– Technological readiness and rate of early deployment of lignocellulosic and biowaste biofuels and PtL which RD&D support can accelerate

– Accessibility of affordable renewable electricity for SAF production and the scaling of cost-competitive green hydrogen as a required element for several SAF production pathways[32]

– Scale of imports of waste oil and lignocellulosic feedstocks for production, given the necessary controls and potential bans on imports from regions with low environmental safeguards

– Allocation of sustainable feedstocks and fuel production capacity to the aviation sector

– Existence and effective enforcement of tight sustainability criteria acceptable to the industry.

Harmonization
Nations can also benefit from the pursuit of a supranational harmonized approach to feedstock sustainability. Global baseline standards have the potential to allow for smoother international trade in SAF, reducing administrative complexities and competitive distortion as more countries promote SAF use.

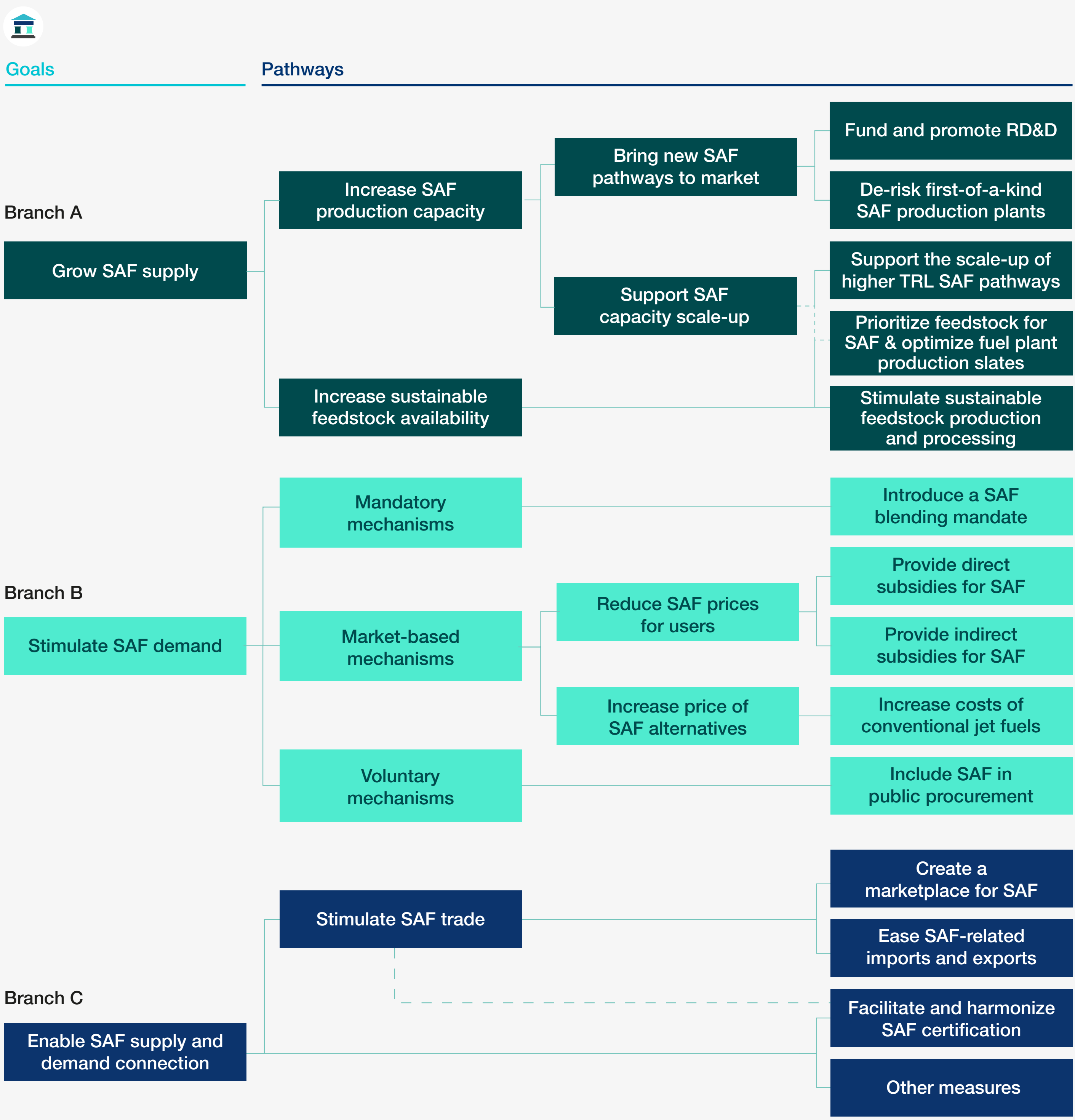
ICAO has been working on a global "umbrella" requirement for SAF sustainability, with further guidance pending. The SAF Ambassadors support ICAO in its efforts and encourage the development and continuous improvement of the requirements to further allow governments and industries in all regions to ramp up SAF production and use with a common understanding of sustainability.

2.2 Issue tree: Supply, demand and enabling policies

This toolkit uses an issue tree as a policy aid, sectioned into supply, demand and enabling branches, with potential decision pathways and policies detailed on each branch. Policy-makers using this decision-making aid should conduct their own cost-benefit and regulatory impact analysis before proceeding with implementation.

It includes 34 possible policy options, with 14 featured in-depth. Each of the 14 featured policies are included as the result of additional available implementation guidance rather than as an indication of higher priority. For each, this section details the need and various attributes, including implementation considerations, potential advantages, value-chain impacts, impact magnitude, anticipated cost burden allocation, cost profiles for government implementors, policy categorizations, and examples of previous or similar use.[33]

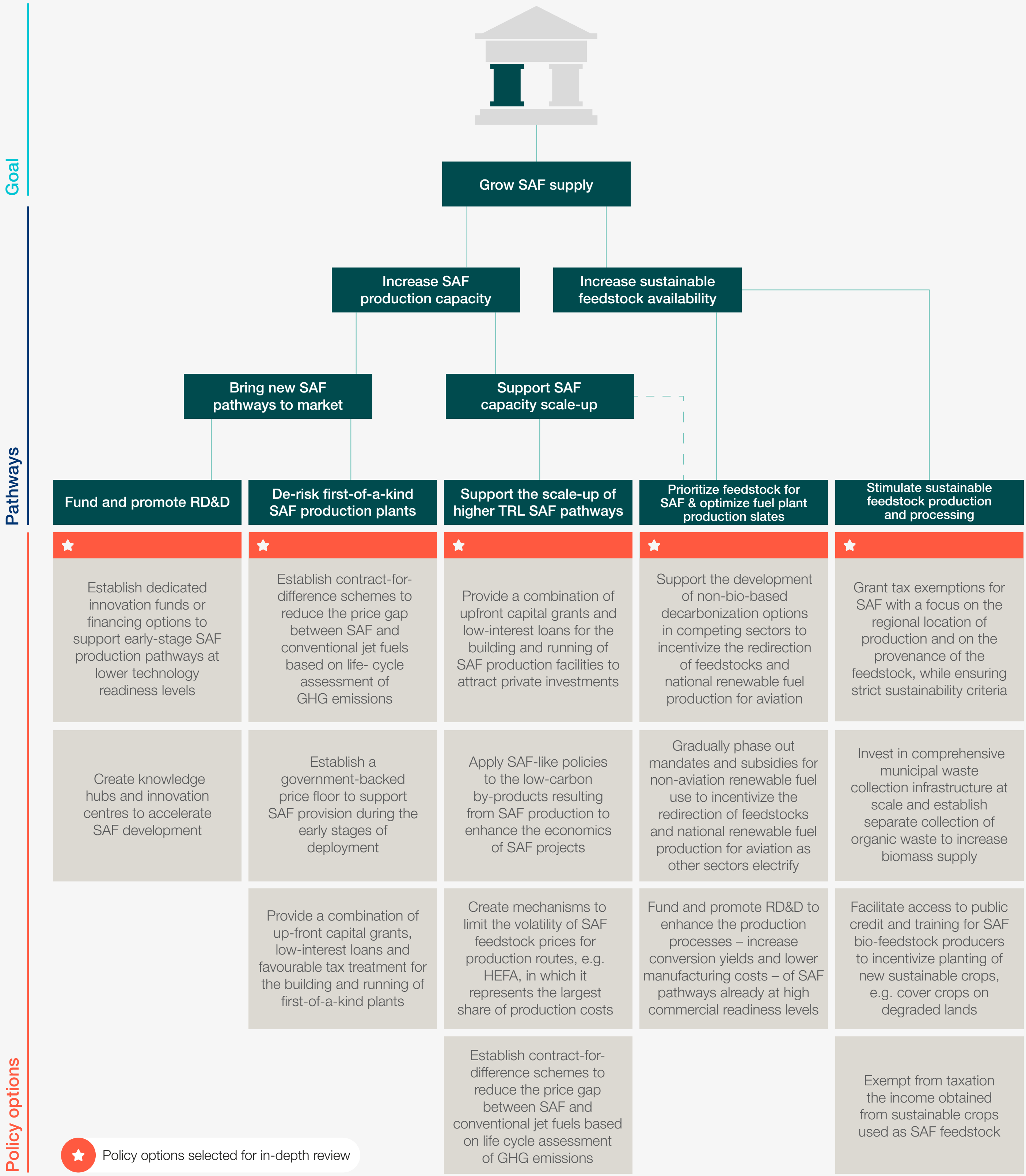
FIGURE 6 **Issue tree with supply, demand and enabling measures for a SAF market at scale**



2.3 Branch A: Supply-side measures to support SAF deployment

Branch A explores policies to grow the sustainable supply of SAF through increased production capacity and feedstock availability. Policies marked with a star have an in-depth analysis.

FIGURE 7 **Supply-side measures and their supporting policies**



Fund and promote SAF research, development and demonstration (RD&D)

Of the seven SAF production pathways approved by international standards organization ASTM International, HEFA (hydroprocessed esters and fatty acids) is currently the only one that can be deployed at scale based on its technology readiness level (TRL). However, supply constraints will limit the use of waste oils in aviation and other feedstocks and pathways can offer better life-cycle emissions reductions. Public RD&D investments in emerging SAF technologies are critical to broader feedstock availability, increased SAF production and lower prices. Novel production pathways that are expected to scale in the near future and attract industry interest include: AtJ, G/FT, and PtL.

Supply	Policy type	CO_2 reduction impact	Impact point	Cost profile
Innovation funds	Economic	Moderate	Fuel production	Well-defined; governments pay

Policy option: Establish dedicated innovation funds or financing options to support early-stage SAF production pathways at lower TRL

Public support for SAF RD&D may include funding for academic research, innovation challenges, loan guarantees, investment de-risking agreements, and grants or other fiscal incentives for private sector investors. Governments can also conduct RD&D at their institutions and make the results available to all stakeholders. Such mechanisms can easily be put in place and governments can target public investment and limit it to the time needed to upscale early-stage projects.

Implementation considerations

Return on investments: Investments in unproven technologies are risky, both economically and politically. Results are difficult to predict or measure and productivity effects are only achieved over the mid to long term.

Policy target and length: Long-term technology RD&D should match with equally long financing policy frameworks to attract and mobilize researchers and incentivize private sector engagement in the innovation processes. When directing funds, consideration should be given to locally available feedstocks, which may provide competitive advantages in the technological development of the production pathways being supported.[34]

Evaluation*:* Not all projects will result in long-term workable solutions. Clear guidelines and realistic decisions points will need to be in place to determine when to continue funding and when to stop RD&D projects that are not delivering expected results.

Demonstrations: Early-stage funding is only one part of the process and should be coupled with demonstration or pilot opportunities as greater TRL is achieved. Industry is more likely to support demonstrations involving multiple players in the supply chain for continuation.

Standards approval: RD&D should also include provisions or support for international standards, such as ASTM or United Kingdom Defence Standards (DEF STAN), and approval for new or developing production pathways, including, where appropriate, increasing blending limits from 50% to100%

Examples

The United Kingdom Green Fuels, Green Skies (GFGS) Competition supports first-of-a-kind SAF plants, with up to £15 million in grant funding on offer in 2021/2022. Eight industry-led projects are on the shortlist for this funding.[35]

In September 2021, the US Government announced its Sustainable Aviation Fuel Grand Challenge, which includes several initiatives and competitions, including $61 million to fund projects aimed at scaling up novel SAF pathways.[36]

De-risk first-of-a-kind SAF production plants

Novel SAF production pathways, such as PtL, G/FT and AtJ, have the highest potential to scale and the most sustainable sources of feedstock. The technology and market risks associated with developing these less mature pathways, however, might be a barrier to private investment. Tailored public support for investments will be needed to de-risk first-of-a-kind SAF production facilities. These mechanisms could take many forms, including blended finance agreements, grants and loan guarantees, contracts for difference, and more.

Supply

Contract for difference

Policy type
Economic

CO_2 reduction impact
High

Impact point
Fuel production

Cost profile
Variable; governments pay

Policy option: Establish contract-for-difference (CfD) schemes to reduce the price gap between SAF and conventional jet fuels based on life-cycle assessment (LCA) of GHG emissions

There are a variety of de-risking mechanisms possible for SAF production facilities, with the most appropriate depending on the value-chain positioning of the institution bearing risk. CfD programmes aim to bring long-term certainty to investors and other renewable energy schemes already use them.[37] By guaranteeing purchase, they minimize investment risk by locking in demand to return capital investments.

They are used to partially, or entirely, bridge the price gap to fossil fuels by providing guarantees to fuel producers that governments (and ultimately customers) will pay the difference between the market price of conventional fuels and the price needed to produce cleaner alternatives. Often, a competitive reverse auction determines a “strike price”. If the market price the producer receives is lower than this strike rate, government funds meet the difference.

Implementation considerations

Policy duration: CfD schemes need to be sufficiently long to match the necessary investment cycle in SAF plants and cover the long-run costs of new low-carbon technologies. This, in turn, can cause technological lock-in effects and become a significant burden on government budgets.

Tailoring: CfD mechanisms can be tailored to stimulate SAF production from specific pathways or specific feedstocks, which would be advantageous in promoting technologies with higher GHG savings potential that are yet to be cost-competitive. However, higher customization might lead to an instrument that is too complex to operationalize or insufficient competition if auctioning is used.[38]

Funding: Given the expected cost differential between SAF and conventional fuels and the scale of SAF production needed, CfDs could be costly for government budgets. In other renewable energy sectors, funding for such programmes often comes from dedicated green levies and taxes on the general market. In an aviation context, this may be more difficult to apply due to limitations on cross-border taxation and levies and may indirectly increase fuel prices for consumers.

Allocation: CfDs should be given based on GHG savings rather than volumes, as the former is a better proxy of the policy goal and can steer fuel production from advanced technologies that offer the greatest carbon reduction potential.[39]

Example

The SDE++ (stimulation of sustainable energy production and climate transition) programme in the Netherlands provides subsidies via CfD for the use of techniques for the generation of renewable energy and other CO_2-reducing methods. The programme has a subsidy intensity limit varying from 60-300 €/tonne of CO_2 avoided. CfDs will be awarded for a period of 12-15 years and a competitive tender will select recipients.[40]

Support the scale-up of SAF pathways at higher technology readiness levels

Even after SAF production pathways reach higher TRL challenges remain for commercial scale-up. Mature production pathways continue to be subject to a variety of other risks – market, regulatory, political, etc. – that can inhibit the attraction of investment. Public support policies to de-risk investments and promote a level playing field with conventional jet fuels are necessary to lower investment outlays and accelerate SAF production deployment rates. As with low-TRL technologies, these mechanisms could take many forms, including blended finance agreements, grants and loan guarantees, contracts for difference, and more.

Supply	Policy type	CO_2 reduction impact	Impact point	Cost profile
Grants and low-interest loans	Economic	High	Fuel production	Variable; governments pay

Policy option: Provide a combination of up-front capital grants and low-interest loans for the building and running of SAF production facilities to attract private investments

Fiscal incentives and public financing, together with blending mandates, are the most widespread policy instruments used to promote renewable fuel production, distribution and consumption.[41] De-risking measures via risk diversification can be just as effective in crowding-in supportive investments.

Examples include: capital grants, which are commonly used in renewable energy projects to cover development costs, reduce financial burden, and bridge viability gaps; and low-interest loans, which can reduce the weight of debt servicing costs, notably on the first years' cash flows – if they include a grace period – and spread-out investment costs over the asset's economic life.

Implementation considerations

Eligibility criteria: Projects can be selected via competitive and merit-based processes. Incentives for SAF plants can be technology agnostic as a combination of different output routes will be needed to scale volumes significantly. But only plants that produce SAF from feedstocks that comply with agreed sustainability criteria should be eligible.

Combined incentives: Up-front capital grants alone might not create the necessary incentives to deliver viable projects in the long run. Combining grants with financial instruments, such as low-interest loans, can provide incentives for the delivery of higher quality projects by maintaining the need for the invested plants to generate sufficient revenues for debt repayment over time.[42]

Limited effects: For the SAF pathways in which feedstock represent a large portion of the overall SAF cost, such as HEFA, these de-risking effects for the building and running of new SAF plants can be limited.

Policy duration: Incentives with a long-term perspective generally have a higher de-risking potential than others. Instruments that are not dependent on public budget allocations are also considered to have a higher de-risking potential, particularly when the political commitment to future budget allocations is uncertain.

Additional forms of support: Government guarantees to cover the risk of default in the final stages of a production plant's development can also serve as a financial de-risking instrument.[43]

Examples

The US Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Programme provided loan guarantees of up to $250 million to fund up to 80% of the total eligible project costs for the development, construction and retrofitting of commercial biorefineries and biobased product manufacturing facilities. The US Government has announced a further $3 billion in loan guarantees to scale up SAF projects.[44]

Brazil's Renovabio Programme provides low-interest loans of up to BRL100 million to biofuel producers via the National Bank for Economic and Social Development. A grace period of 24 months is granted and interest rates are linked to CO_2 emissions reduction targets set by the programme.[45]

Prioritize feedstock for SAF production & optimize fuel plant product slate and SAF conversion yields

The demand for bioresources is increasing significantly as different sectors look to biomass feedstock to provide their decarbonization solutions. Europe's use of biofuels multiplied by a factor of 25 between 2000 and 2020.[46] While environmental benefits are not always guaranteed, such as with maize-based ethanol in the United States,[47] sustainable options are available but require strategic allocation. Demand from competing sectors such as power and road transport can constrain the availability of renewable feedstock for SAF production or the fraction of SAF[48] produced at renewable fuel plants. Aviation remains highly dependent on renewable liquid fuels for the immediate to medium-term, however, whereas others have alternative decarbonization options through renewable electrification.

Supply	Policy type	CO_2 reduction impact	Impact point	Cost profile
Decarbonization of other sectors	Economic/ regulatory	High	Fuel production	Well-defined; governments pay

Policy options: Support the development of non-bio-based decarbonization options in competing sectors to incentivize the redirection of feedstocks and national renewable fuel production for aviation

SAF volumes could increase significantly in the short-term if renewable fuel producers shift existing fuel production to jet fuel. CST analysis shows that Europe's existing biodiesel production facilities could meet 10% of all regional jet fuel demand if prioritized for SAF production.[49]

To stimulate the shift without harming existing markets, governments need to gradually reduce demand for renewable resources in competing sectors where other decarbonization options are closer to cost competitiveness. Transitioning to clean electricity as the main source of final energy can, in fact, represent an opportunity for governments, as it is currently the cheapest and most efficient way to promote the decarbonization of economies.[50]

Policy priorities to electrify competing industries are sector and region dependent; policy-makers must find the framework that is most appropriate to their larger energy transition strategy and localized context. For example, policies could drive the transition for light-duty vehicles via charging infrastructure investment, purchase incentives for battery electric vehicles, fuel economy standards, and bans on or the phased retirement of internal combustion engine vehicles.[51]

Implementation considerations

Opposition: Despite its hard-to-abate characteristics, aviation does not have social licence over other industries and pushback from competing sectors might be expected, particularly from road transport biofuel producers.

Short-term emissions: The emission life-cycle savings from producing renewable fuels for other sectors might be higher than those achieved by producing SAF, such as the renewable diesel vs SAF from HEFA pathway. Equally, electrifying these sectors may not currently be the most environmentally sound option, especially if the green infrastructure required is not yet in place.

Further scaling: Although the SAF output potential from diverting current renewable fuel production from other sectors for aviation use can be significant in the short-term, it will not fundamentally change the techno-economic scenario of SAF production in the long run, due to feedstock constraints. Newer production technologies with lower TRLs need to be brought to market.

Example

The European Union's Fit for 55 Legislative Package proposes a ban on new fossil fuel-powered vehicles after 2035 and potential support for lower-income families to convert to electric cars.[52]

Stimulate sustainable feedstock production and processing

Feedstock production and collection is expected to be one of the most labour-intensive areas in the SAF value chain. Moreover, not all countries or regions will have the same production capacity and there is a risk producers will simply import the lowest cost feedstock available, potentially resulting in carbon leakage. In the long-term, as SAF increasingly replaces fossil jet fuel, local feedstock supply for local production is an important factor for an efficient global market. However, it takes several years for feedstock supply chains to reach optimal levels, so local production needs incentives today if countries want to achieve ambitious SAF goals for 2030 and 2050.

Supply	Policy type	CO_2 reduction impact	Impact point	Cost profile
Tax exemptions for SAF	Economic	Moderate	Feedstock production and processing	Variable; governments pay

Policy option: Grant tax exemptions for SAF with a focus on the regional location of production and the provenance of the feedstock while ensuring strict sustainability criteria

If well monitored, controlled and enforced, such incentives can encourage sourcing of biomass and renewable feedstock from local and regional producers, stimulating local economies and maximizing supply chain logistics efficiencies. Moreover, by specifying which feedstocks will be eligible for incentives, governments can stimulate the production and collection of the most sustainable feedstock for the local area, avoiding fuel production from environmentally sensitive areas, such as peatlands, wetlands and primary forests.

Implementation considerations

Carbon leakage: Inadvertent creation of supply chain inefficiencies and carbon leakage by artificially stimulating feedstock production in regions that might not be natural candidates is a possibility with such policies. For example, incentivizing the production of hydrogen as a SAF feedstock in areas distant from fuel synthesis plants will result in transportation inefficiencies; feedstock production should be suitable for the local region.

Oversight: Verification measures and traceability mechanisms need to be in place to ensure that feedstock types and origins not included in the incentive programme are not mislabelled and mixed into the supply chain. The responsibility for proving compliance generally lies with the fuel producers but also requires strict monitoring and evaluation. Failure to properly enforce this mechanism could result in overall life-cycle emissions higher than those from the use of conventional jet fuels.

Amplification of benefits: As the production and harvesting of raw materials is among the most labour-intensive areas, for bio/waste-based fuels, governments can amplify the socio-economic impacts by including small-scale producers/ collectors among the beneficiaries.

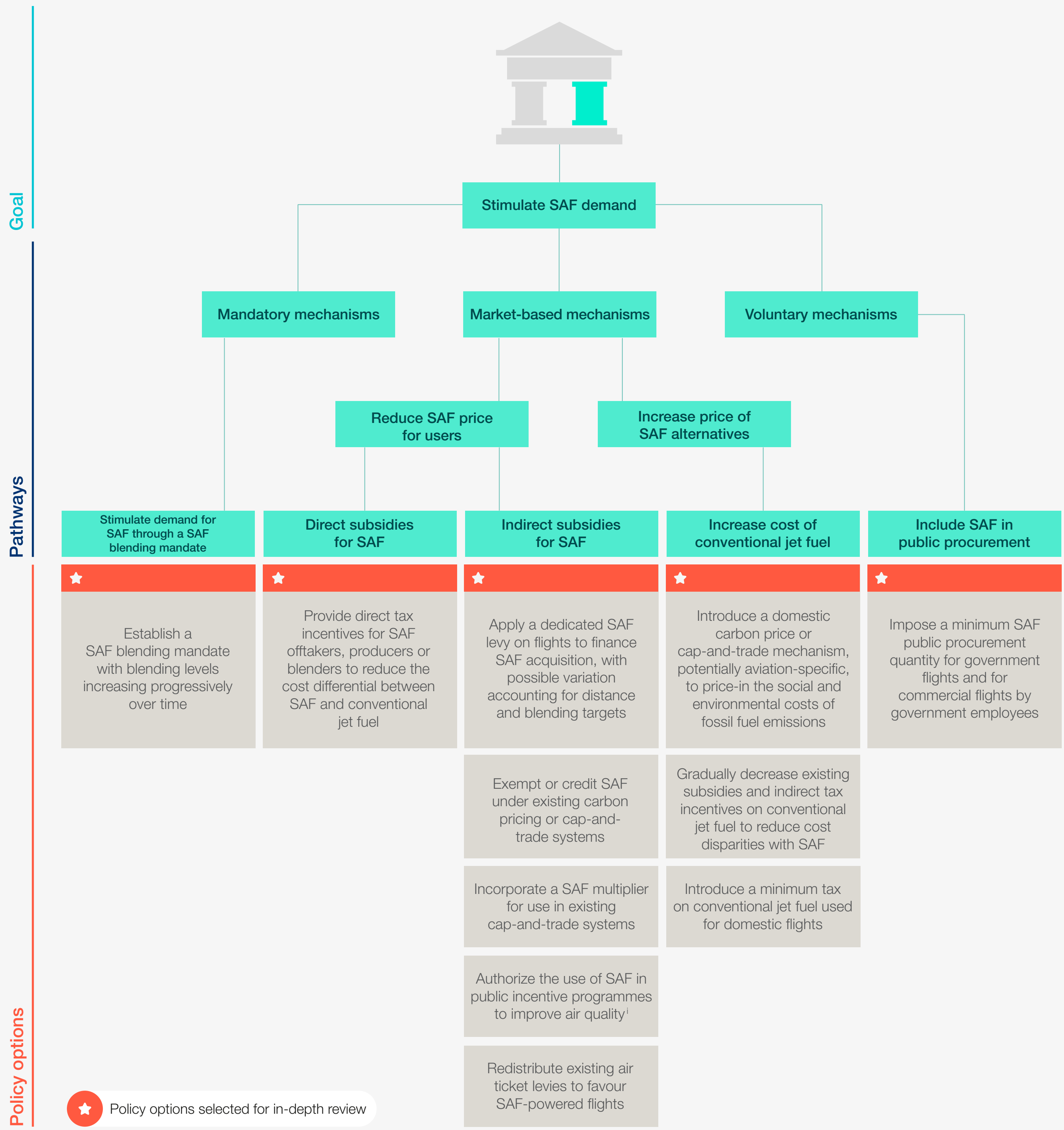
Example

Brazil's National Biodiesel Production and Use Programme provides tax incentives for biodiesel producers who purchase feedstocks from family farmers. The minimum purchase percentages for eligibility vary from 20% to 40% according to the region's socio-economic status.[53]

2.4 Branch B: Demand-side measures to stimulate SAF uptake

Branch B explores instruments to increase SAF uptake by providing policy options aimed at stimulating voluntary, mandatory and market-based demand. Policies marked with a star have an in-depth analysis.

FIGURE 8 **Demand-side measures and their supporting policies**



i: Ghatala, F., *Sustainable Aviation Fuel Policy in the United States: A Pragmatic Way Forward*, Atlantic Council, 2020

Stimulate SAF demand through a SAF blending mandate

On average, currently available SAF costs two to four times more than conventional jet fuel and is unlikely to scale to significant levels based on voluntary demand alone with current pricing paradigms. The cost differential between SAF and conventional jet fuel is expected to narrow as economies of scale and learning effects take hold, but cost competitiveness is unlikely to be achieved without policy support or correction of markets failing to effectively price environmental impacts. Policies aimed at creating long-term, predictable demand to de-risk investments in supply chains are key levers for widespread SAF deployment.

Demand	Policy type	CO_2 reduction impact	Impact point	Cost profile
Blending mandate	Regulatory	High	Fuel offtake	Well-defined; industry/ consumers pay

Policy option: Establish a SAF blending mandate with a blending level that increases progressively over time

Blending mandates create an obligation on one or more parties in the value chain – fuel suppliers, blenders, airports, airlines – to increase the share of SAF in the jet fuel market. Blending mandates send an unequivocal market demand signal and have the advantage of imposing no direct burden on public funds.

Implementation considerations

Sub-mandates: A headline SAF blending mandate can be coupled with sub-targets for specific production pathways to accelerate the cost reduction of lower TRL technologies with higher emissions saving potential, such as PtL.

Targets: Blending targets should be well-quantified and presented with appropriate lead-times. They should also increase progressively at a technically feasible rate to enable ramp-up in capacity and avoid sustainability risks from over-sourcing limited feedstocks. Blending quotas can be based on volumes or GHG intensity reductions. If using volumetric targets, a minimum threshold for SAF life-cycle GHG emissions intensity should be required and tightened over time to drive the development of technologies with higher GHG savings potential.[54]

Oversight: A regulatory authority may need to be in place to monitor and verify the process and issue compliance certificates to obligated parties according to the volumes of SAF produced, blended or used, as well as to ensure stakeholders achieve the mandated blend of SAF and that the SAF used meets relevant life-cycle eligibility requirements. Importantly, the cost of non-compliance should be higher than the cost of complying with the mandate.

Market distortions: A SAF mandate will increase fuel costs for flights. Since the geographic scope of national mandates is limited to flights taking off from a country, there are potential competitive distortion risks. They could take the form of demand relocation, modal changes, and fuel tankering, which could undermine policy effectiveness. Although these negative effects may only become notable at higher blending percentages, some form of financial support may be required before proper scale is reached.

Availability of SAF and associated technologies: Depending on the maturity of national renewable fuel markets, other policies may be needed to ensure that the necessary production technologies and enough fuel from sustainable sources are available for aviation to meet the blending targets set.

Risk of unsustainable feedstock: If demand resulting from mandates outpaces supply-chain capabilities, there is a risk of carbon leakage and uptake of unsustainable feedstocks. Blending mandates need to be carefully designed to minimize and monitor for these risks.

Implementation mechanism: Whether blending mandates are imposed on fuel suppliers, airports, airlines or a combination of parties is an open question that should be considered.

Market-based mechanisms: Ensuring sufficient and consistent SAF supply at all airports nationally may prove challenging, particularly when first implementing mandates. Consideration should be given to the establishment or continuation of existing trading schemes to manage over- and undersupply at different locations. Market-based mechanisms can also reduce the overall cost of a mandate by incentivizing SAF supply in the lowest cost locations.

Monitoring and reporting: Provisions should be developed to allow the obligated party and final fuel offtakers, such as airlines, to claim sustainability documentation and associated LCA emissions reductions from fuel they procure under the mandate.

Examples

In 2008, Norway announced a 0.5% blending mandate to apply from 2020, with plans to increase this to 30% by 2030.[55] Currently other supporting policies, including those relating to reporting requirements, are not in place to see this policy realize its full potential.

An EU mandate is currently under discussion as part of the ReFuelEU Aviation proposal issued by the European Commission in its 2021 Fit for 55 package.

Provide direct subsidies for SAF

Direct public subsidies can help address the cost disparity between SAF and conventional jet fuels by reducing SAF production costs or discounting the price for buyers. Subsidies to support price competitiveness are particularly important when environmental harms from fossil fuels are not properly accounted for. Subsidies are widely used to promote solar and wind generation capacity and have been credited with increasing innovation, scaling up volumes and reducing reliance on fossil fuels in other sectors.[56]

Demand	Policy type	CO_2 reduction impact	Impact point	Cost profile
Direct tax incentives	Economic	High	Fuel offtake	Well-defined; governments pay

Policy option: Provide direct tax incentives for SAF offtakers, producers or blenders to reduce the cost differential between SAF and conventional jet fuels

Governments can provide tax incentives based on units of qualifying SAF produced, blended or used above a pre-determined minimum LCA savings threshold. The higher the emissions reduction per unit of fuel beyond this threshold, the larger the tax incentive. This approach aims to stimulate the production of SAF from technologies with higher GHG savings potential, targeting spending towards only the most impactful technologies. Such tax incentives can have immediate impacts on SAF costs and can be adjusted as SAF production reaches economies of scale.

Implementation considerations

Design: The exact design of the measure will depend on context-dependent national tax frameworks and can be applied at one or more points in the value chain; producers, blenders, airlines, consumers, and more.

Access to incentives: In many countries, companies can offset their tax liabilities with qualifying expenses, particularly when investing in early-stage development and facilities projects. However, such incentives may not be available until a facility begins to generate tax liabilities, discouraging early investments in SAF production pathways that may be far from commercialization.[57] In such situations or where fuel producer tax rates are already low, it might be necessary to couple SAF-based tax reductions with additional supporting measures such as tradable tax credits to reduce the price disparity with fossil fuels.

Altering existing fuel subsidies: Fossil fuels often receive large subsidies through direct payments, price limiting, and tax incentives. As these existing subsidies further increase the price delta between SAF and conventional jet fuel, shifting existing subsidies from fossil jet fuel to SAF provides a potentially highly effective incentive without impacting costs to government.

Policy durability: To create sufficient certainty for investment, the duration of tax incentives should match the timeframe for return on investments.

Examples

The Second-Generation Biofuel Producer Tax Credit (SGBPTC) in the United States allows a credit against the fuel producer's tax liabilities of up to $1.01/gallon of second-generation biofuel, such as from lignocellulosic, sold and used by the purchaser.[58] The US Government also announced a dedicated sustainable aviation fuel tax credit as part of its Build Back Better Agenda.

Provide indirect subsidies for SAF

Indirect subsidies also aim to address market inefficiencies and reduce the price disparity between SAF and regular jet fuels but, unlike direct subsidies, do not provide a specific monetary pay-out to the beneficiary.

Demand	Policy type	CO_2 reduction impact	Impact point	Cost profile
Dedicated SAF fee	Economic	Moderate	Fuel offtake	Well-defined; industry/ consumers pay

Policy option: Levy a dedicated SAF fee on flights to finance SAF acquisition, with possible variation accounting for flight distance and SAF blending target levels

Charges and fees are common in aviation and customers generally pay them at the point of ticket purchase. A dedicated SAF fee would allow airlines and partners to bridge the cost differential of procuring SAF and simultaneously improve awareness and transparency for customers on SAF's increasing role throughout the aviation sector. A central institution could procure SAF, such as through reverse auctions, and blend it with regular jet fuel within certified limits. When applied based on destination, such a fee would also ensure equal treatment for all airlines regardless of location and number of intermediate stops. Fees could be adjusted over time to reflect a rising SAF blending target and actual passenger numbers.

Implementation considerations

Opposition: Industry is likely to resist levying additional fees on ticket prices, particularly given the COVID-19 pandemic's ongoing economic impact. Liaising closely with industry at each step, determining appropriate international and/or domestic applicability, and ensuring proceeds from such fees are used for the direct purchase of SAF or reinvested to support SAF-related activities could mitigate opposition.

Application: Such a fee could be mandatory or voluntary. Mandatory fees provide a more consistent income stream than voluntary schemes and add a de-risking element for SAF producers but may receive greater pushback, especially in markets where passenger fees and taxes are already high.

Recipient: Policy-makers should consider whether revenue from the fee is directed to the government, the airport or the airline. From a transparency point of view, the entity that procures the SAF may be the most appropriate recipient; however, national accounting policies and regulations may require the development of alternative fee collection and distribution systems.

Cross sectoral approach: States should also consider whether a sustainable fuel fee should be aviation-specific or apply to all transport sectors as part of a broader national policy.

Monitoring and collection: A centralized monitoring and collection system would need to be established. It may make sense to use existing airline infrastructure to do this, with the fee transparent for passengers.

Example

Swiss International Air Lines applies a voluntary SAF fee where passengers can opt to pay the difference between the SAF price and conventional jet fuel for their flight. Swiss Air guarantees that the SAF purchased will be put into circulation within six months.[59] However, this is not a national policy but rather an airline initiative.

Increase the cost of conventional jet fuel

Another way of achieving cost competitiveness for SAF is to increase the price of its immediate alternatives. In general, prices for fossil jet fuel do not factor in their societal or environmental costs. In fact, many countries still apply significant subsidies or indirect tax incentives that artificially suppress prices. These market distortions are a roadblock to scaling up SAF.

Demand	Policy type	CO_2 reduction impact	Impact point	Cost profile
Domestic carbon pricing or cap-and-trade	Regulatory	Moderate	Fuel offtake	Well-defined; industry/ consumers pay

Policy option: Introduce a domestic carbon price or cap-and-trade mechanism, potentially aviation-specific, to price-in the cost of GHG emissions for fossil fuel

A cap-and-trade system can be used to put a price on fuel emissions and encourage fuel switching to low-carbon alternatives. A cap is set on the total allowable GHG emissions by regulated entities, tightened over time to reduce total emissions. The initial GHG emission certificates can be allocated either via auction or based on historical production. If a participant exceeds its annual emissions cap (and has not purchased additional emissions allowances), fines are imposed.[60]

Implementation considerations

Applicability: National carbon pricing schemes imposed on all departing flights could result in jurisdictional (or potentially geopolitical) disputes due to different international and national regulatory schemes, such as CORSIA and European Union Emissions Trading System (EU ETS). Limiting the scope of the policy to domestic flights would circumvent the sensitivity but would also limit the carbon savings potential, since it is mid- and long-haul flights that emit the most GHGs.

Carbon prices: Carbon prices need to be sufficiently robust to effectively promote a fuel switch to SAF. To reduce uncertainty in systems and avoid deterring investments in SAF, carbon price floors can be implemented.

Cost-driven limitations: Technology-agnostic systems tend to prioritize more mature (and less costly) technologies, limiting the development of new technological pathways with higher GHG savings potential.

Exemption requests: Aviation is subject to strong international competition and it may be necessary to allocate certificates freely to avoid burdening airlines with higher costs than competitors not subject to the pricing scheme. If allocation becomes overly generous, however, prices are unlikely to support fuel switching.

Double counting: Special attention should also be given to the verification of potential double counting between CORSIA, EU ETS and emissions trading at the domestic level. Where possible, national standards should align with international ones to ease compliance and reporting by airlines, airports and fuel producers.[61]

Examples

Under the EU ETS, air carriers must surrender carbon allowances from intra-EU flights, each representing 1 tonne of CO_2, equivalent to their emissions reported in the previous year. The system reduces the allowable CO_2 emissions every year and restricts the number of permits within the marketplace to drive polluters to progressively reduce their CO_2 footprint.[62]

Under the US State of California's Low Carbon Fuel Standards, SAF producers can voluntarily opt into the programme to generate credits to compensate for fossil fuel generation obligations or sell the credit to other deficit generators.[63]

Include SAF in public procurement

Public procurement can be a valuable supplementary tool in pioneering the production and use of SAF by generating critical early demand that helps de-risk and kick-start SAF production, while also serving as a leading example for private offtakers.

Demand	Policy type	CO_2 reduction impact	Impact point	Cost profile
Minimum levels of public procurement	Regulatory	Low	Fuel offtake	Well-defined; governments pay

Policy option: Impose a minimum public SAF procurement quantity for military and state flights, and for commercial flights by public servants

Governments can procure SAF directly from fuel providers via competitive tenders for use on state-owned aircraft and indirectly from airlines by ensuring that public servants on commercial flights cover the price premium between regular tickets and tickets for SAF-fuelled flights. The participating airlines then guarantee and provide evidence that the publicly acquired SAF volumes will be put into circulation within a given timeframe. This encourages the growth of a lead market for SAF and is simple to implement in the short term.

Implementation considerations

Scale: Quantities of jet fuel procured by governments may not be representative of overall national jet fuel demand and may not be sufficient on their own to trigger tipping points in SAF scale-up. Public procurement will therefore likely function as a supplementary early measure rather than a major change driver.

Delivery: Governments pioneering SAF uptake may face limited competition for tenders, challenges in fulfilling technical requirements, and supply shortages until value chains reach minimum operational levels.[64]

Jurisdiction: Depending on national laws and budgetary processes, military flights, which tend to represent the largest portion of state's jet fuel consumption, may be out of scope for general government procurement.

Monitoring and collection: A centralized monitoring and collection system would be needed to ensure ongoing airline and fuel provider compliance. Records would need to be accessible for government budgetary reporting as this policy involves the use of public funds.

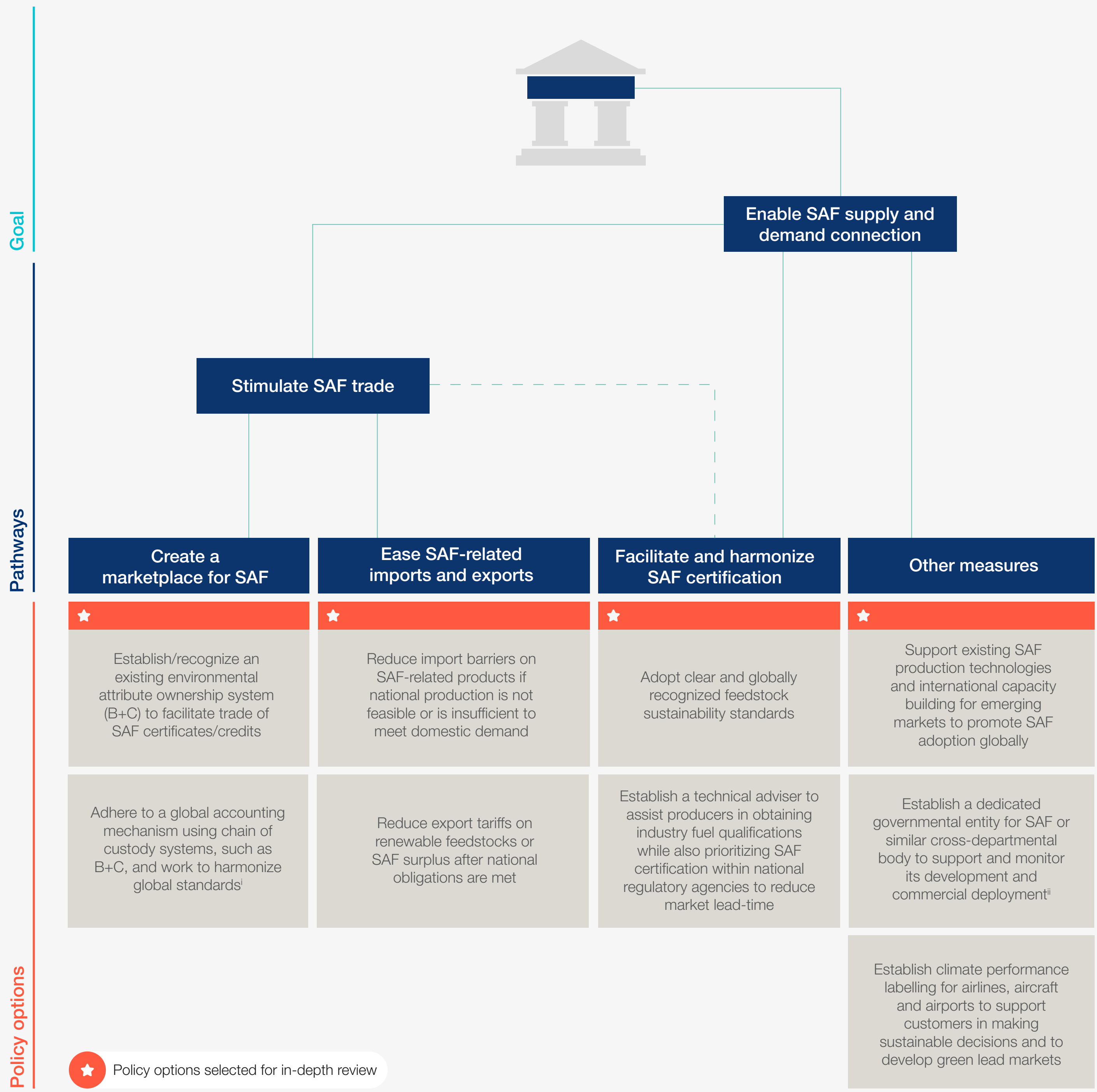
Example

The Government of the Netherlands participates in KLM's Corporate SAF Programme whereby public servants flying on KLM pay the premium difference between conventional jet fuel and the SAF equivalent for their flight.[65]

2.5 Branch C: Enabling measures and systems to facilitate SAF scaling

Branch C explores instruments to connect and amplify the effectiveness of supply and demand measures by easing scaling barriers and promoting trade. Policies marked with a star have an in-depth analysis.

FIGURE 9 **Enabling measures and their supporting policies**



i: International Air Transport Association (IATA), Sustainable Aviation Fuels: Fact sheet, May 2019

ii: Sustainable Aviation, *Sustainable Aviation Fuels Road-Map: Fuelling the Future of UK Aviation*, February 2020

Create a SAF marketplace

For SAF to reach global trading volumes similar to those of conventional jet fuels, large-scale production and harmonized technical and sustainability specifications are needed in addition to corresponding market mechanisms to ensure efficient trade of SAF and its environmental attributes.

The creation of a national or global SAF marketplace could expand the typical bilateral relationship between producers and buyers, providing better information and competitive prices to end-customers. Improved supply-chain transparency could allow offtakers to source SAF volumes and their virtual attributes from their more economically advantageous points, in turn stimulating SAF production from the most efficient technological pathways, most sustainable feedstocks, and most socio-economically responsible processes.

Enabler	Policy type	CO_2 reduction impact	Impact point	Cost profile
Ownership transfer system	Regulatory	High	Fuel offtake	Well-defined; industry/ consumers pay

Policy option: Establish or recognize an existing environmental attribute ownership transfer system, such as book and claim (B+C), to facilitate and promote the trade of SAF volume credits or GHG emissions reductions

B+C accounting systems allow fuel offtakers, such as airlines and airports, to account for SAF's environmental benefits without the need to also possess and physically consume SAF. This means SAF does not need to be carried all the way to a specific aircraft – instead it can be delivered to a point of consumption that is closer to the production site or has more efficient logistics. There, SAF can be physically mixed and sold as aviation fuel. The right to claim the GHG emissions reductions from the SAF consumed is traded on a separate online market in the form of certificates or credits, such as the Sustainable Aviation Fuel Certificate (SAFc) framework pioneered by CST.[66]

Such a system has many possible advantages, including facilitating SAF production in regions with lower production costs; minimizing transport-related carbon emissions; no SAF volume restrictions for offtakers due to logistical or local production constraints; as well as fraud avoidance via associated track and trace mechanisms.

Implementation considerations

Design: Functional requirements must be determined first. For example, environmental attributes can be issued based on fuel volume or overall life-cycle emissions reductions. For volumetric models, it must be determined at which point in the supply chain the shift from physical measurement to virtual certificates will take place and how to create data tracking and verification beyond the decoupling point. For LCA models, a suitable comparable emissions baseline for conventional jet fuel must be defined. Both models present trade-offs between implementation complexity and carbon accounting accuracy.

Certificate issuance is recommended as a verification measure, as ideally only SAF volumes exceeding compliance requirements should be eligible for tradable credits.

Harmonization: Although emissions ownership needs to be tied to a region, aviation operations are global. If national B+C systems are not harmonized and interlinked to allow for trade, a patchwork of accounting standards will increase market uncertainty and create an administrative burden for the industry. National B+C systems should align with global or regional systems to simplify SAF uptake and compliance and facilitate international trade.

Oversight: A singular independent entity should be responsible for certificate and credit issuance. A registry should govern how credits are recognized and transferred, ensuring ownership can be assigned to the purchasing parties, avoiding double counting, and providing assurance that emissions reductions are credible.

Costs: For countries where the issuing of certificates or credits are expected to be low or sporadic, it may be challenging to cover the operational costs of a national registry. Participation in existing regional schemes may be an option in such cases.

Reputation risk: Public opinion might turn against B+C schemes if passengers discover that despite paying for SAF (voluntarily or not), it may not power their aircraft or even be in their country. Clear information sharing with aviation customers about how the scheme works will be needed.

Examples

The CST initiative's SAFc sets out a framework for the transfer of SAF certificates among private companies that could be implemented globally.[67] Many airlines offer voluntary B+C schemes to passengers and corporate customers.[68]

The USA Environmental Protection Agency Moderated Transaction System is designed to allow companies to report and track transactions for national fuel programmes, such as the Renewable Fuel Standard and Gasoline Sulphur programme.[69]

Ease SAF-related imports and exports

Restrictive import and export measures to control national fuel trade streams can negatively influence the development of SAF supply chains worldwide. When nations set import barriers too high in an effort to protect domestic producers, it can exacerbate the already notable cost difference between SAF and conventional jet fuels. Other nations may have the potential to produce cost-competitive SAF beyond their national needs but choose to elevate export barriers to guarantee the use of renewable fuels within the country, providing no incentive to expand supply chains.

Easing international SAF trade will alleviate these market failures and contribute to industry decarbonization by allowing for the sourcing of sustainable feedstocks – and the production of SAF – where it is more economically viable and environmentally sound to do so.

Enabler	Policy type	CO_2 reduction impact	Impact point	Cost profile
Reduce SAF import barriers	Economic	Moderate	Fuel offtake	Variable; governments pay

Policy option: Reduce import barriers on SAF-related products if national production is not feasible or insufficient to meet the domestic demand

The development of SAF production chains around the world will be necessary to achieve the volumes of SAF needed to replace the use of conventional jet fuel. Some nations, however, might not be able to generate enough sustainable feedstock or SAF to cover their aviation industry emissions reduction ambitions and will, at least in the short term, need to rely on imports. Reducing import tariffs or giving SAF and feedstocks a friendlier trade classification, such as agricultural vs industrial product (some countries impose higher trade barriers on products classified as agricultural),[70] can help bridge the cost differential and serve to keep national SAF production cost-competitive.

Implementation considerations

Oversight: Clear guidelines for importing SAF and robust certification, monitoring and evaluation systems are needed to ensure that trade facilitation does not lead to unsustainable practices in exporting regions.

LCAs: The additional GHG emissions stemming from the need to transport SAF internationally can undermine its environmental benefits. Import tariffs should be linked to SAF LCAs, with more sustainable products – measured at the point of use – enjoying greater economic benefits.

Since SAF needs to be scaled globally and can be made from an extensive range of available feedstocks, the importing of related products should serve as a demand buffer while, in parallel, other mechanisms to increase national production are also put in place, if local production is feasible.

Opposition: Feedstocks or fuel producers looking to expand into the nascent SAF market might push back against competition from foreign products, particularly if nations already have a renewable fuel value chain. Policy-makers should therefore be careful not to disadvantage local SAF supply chains.

International cooperation: An international B+C system would represent a parallel mechanism to help avoid carbon emissions from the transportation of SAF or its feedstocks by allowing the "importing" of the environmental benefits of SAF use without the need to physically transport fuel across borders. States should continue to participate in international discussions on this topic so that any system eventually developed is compatible with national policies.

Example

Asia's Regional Comprehensive Economic Partnership (RCEP) is a free-trade agreement between 15 Asia-Pacific countries expected to phase out tariffs on a host of biofuels and feedstocks.[71]

Facilitate and harmonize SAF certification

The SAF market will need to rapidly develop in the coming years to meet ambitious climate targets. There is a risk that if countries develop these markets in isolation, a patchwork of systems and certification standards will evolve, creating additional complexities, costs and delays for industry participants in production, distribution, compliance and monitoring.

Enabler	Policy type	CO_2 reduction impact	Impact point	Cost profile
Adopt recognized sustainability standards	Regulatory	Moderate	Feedstock production and processing	Well-defined; governments pay

Policy option: Adopt clear and globally recognized sustainability standards for feedstock supply

A key element of SAF sustainability certification relates to feedstock supply. Multiple SAF production pathways have demonstrated viability or are being tested now using different types of bio or synthetic feedstocks. Each feedstock produces different levels of LCA GHG emissions reductions and different sustainability considerations.[72] While nations may seek to determine their own sustainability criteria for feedstock, using internationally recognized standards can facilitate international trade, simplify emissions accounting across different geographies, and keep monitoring and compliance costs as low as possible.

Implementation considerations

Adaptation: Although the benefits of harmonization are clear, this should not prevent policy-makers from going further on sustainability standards or adapting existing sustainability criteria to better reflect local conditions and processes. Ultimately, measuring and reporting on the carbon savings for relevant feedstock is key, along with priority use given to feedstocks meeting high GHG reduction criteria with no or limited sustainability impacts.

Oversight: As a minimum, states should use a sustainability certification scheme to certify and provide reasonable assurance, recognized by an international institution that already exists and is accredited by ICAO, such as International Sustainability and Carbon Certification (ISCC) or RSB.

Imports: Common or equivalent sustainability standards can also generate trust in the import of SAF or feedstock. Countries that rely on SAF imports can be more confident that imports meet the same renewable feedstock and SAF production and processing best practices that have been applied to domestically produced products.

Examples

In this report, the CST SAF Ambassadors group outlines high-level sustainability guidelines for feedstock sourcing and production (see *SAF feedstock sustainability)* that can serve as starter guide. The sustainability guidelines were based on the standards of the ICAO's CAEP – Committee on Aviation Environmental Protection, RSB,[73] and existing CST sustainability analysis.[74]

Other measures to enable supply and demand connection

In addition to measures facilitating certification and stimulating SAF trading, policy-makers may also consider a series of individual but equally important policy instruments to support links between supply and demand on a global level.

Enabler	Policy type	CO_2 reduction impact	Impact point	Cost profile
Support global adoption	Administrative	Moderate	Fuel production	Well-defined; governments pay

Policy option: Support the roll-out of existing SAF production technologies and international capacity building to developing countries to promote the adoption of SAF production globally.

Aviation is a global industry with global emissions impacts; inaction in one part of the world can undermine positive steps to decarbonize elsewhere. A global effort to remove key market, technical and financial barriers to SAF development in all regions is critical. States can support this through direct capacity building, sharing of best practices and lessons learned from their own implementation, supporting the roll-out of commercially ready SAF production pathways, and via participation in global capacity building initiatives run by ICAO and various industry associations.

Implementation considerations

Format: The format of support will vary with willingness and resources available to deliver capacity building interventions, as well as with the receiving states capabilities, plans for resource development, and the scale of support needed. Support should be tailored to ensure that feedstock or SAF produced meets high sustainability criteria.

Support options: For emerging economies that already have expertise in producing renewable fuels, for example, the support to kickstart local SAF production might take the form of market or financing facilitation via reduced barriers to SAF exportation, the provision of export credit insurance or access to financing from national or multilateral development banks. For other regions rich in sustainable feedstocks but with little expertise in non-fossil fuel production, a multiyear capacity building programme might be a better approach. This could be coupled with grant funding to organizations developing training programmes, mentoring, scholarships and other such institutional support aimed at building critical SAF production-related knowledge. Relevant government departments may carry out such capacity building directly, either alone or in cooperation with organizations like ICAO.

Trials and pilots: Where new technologies or processes are being introduced, it may make sense to trial or pilot these prior to scaled implementation. Not all states have experience conducting pilot programmes and may need support in navigating regulatory approval processes, securing funding, and monitoring and evaluation.

International cooperation: Governments and organizations such as ICAO have various capacity building programmes. In recent years, these programmes have been expanded to include SAF and aviation CO_2 reduction. Through these programmes, governments can contribute knowledge and expertise to dedicated workshops and activities, as well as the production of guidance material and case studies.

Confidentiality: Capacity building may involve discussions regarding specific technologies and processes to develop SAF feedstock or convert feedstock to SAF. Some of these technologies and processes may be proprietary. Governments undertaking capacity building activities will have to ensure they do not unintentionally share any proprietary or confidential information. In some cases, it may make sense to conduct capacity building activities in conjunction with producers, manufactures and other key stakeholders, ensuring no anti-competitive behaviour. This may include, for example, workshops or open days where the different options can be explored together.

Example

The ICAO-EU Capacity building for CO_2 mitigation from international aviation project has conducted four SAF use case studies in developing countries. In Kenya, this work led to a pilot programme to reduce aviation emissions at Mombasa Airport.[75]

2.6 Interaction between supply, demand and enabling measures

Any regulatory framework should stimulate supply, demand and enabling measures in a coordinated way to avoid cumulative effects from combined stimuli or a mismatch between supply and demand that interferes excessively with market equilibrium.

The possibility of individual SAF projects qualifying for an array of support instruments could lead to excessive subsidies. These undesirable effects can be mitigated via anticipation of the policy impact on the value chain, adequate monitoring of market activity, and by timely adjustments of regulatory provisions when issues are identified. In general, market-driven programmes such as auctions have proven most appropriate for avoiding the pitfalls of excessive subsidization.[76]

Ideally, a single and balanced policy framework should plan for and implement supply and demand measures, with coordination and planning for when each policy will enter into force. For example, the time span needed for SAF supply chains to mature (the average lead time from plant initiation until commercial operation is around 4 years[77]) might lead to an imbalance between supply and demand if measures to stimulate the latter, such as blending mandates, come into force before SAF plants are operational.

Looking ahead & conclusion

Stable policy and supportive regulations will be critical to enable the SAF scale-up required to achieve sectoral decarbonization by 2050.

Looking ahead – CST and the SAF Ambassadors initiative

The Clean Skies for Tomorrow initiative is working across multiple workstreams and pursuing a multipronged approach to decarbonizing aviation, including continued analytical work on SAF and other decarbonization pathways, crafting a sectoral decarbonization transition strategy, facilitating greater global access to SAF in an equitable manner, and addressing demand signals through its SAFc framework and a blueprint for financing the transition to net-zero emissions.

This toolkit, designed through CST's SAF Ambassadors group, is purpose-built to guide and inform policy-makers around the world in designing and implementing policies to support the scaled deployment of SAF. Drawing from the experience and diversity of the SAF Ambassadors and the CST community, this toolkit presents policy-makers with a range of policy options and related considerations to assist them in taking the necessary steps to support the scaled production and use of SAF. These policy options are a cross-section of the most influential mechanisms but are not prescriptive. Appropriate analysis and adaptation to the local context must precede any implementation.

The SAF Ambassadors group is mission-aligned in serving as an example and inspiration to the global community, doing their part to support the aviation industry's global decarbonization pathway. Participating governments including Costa Rica, Kenya, the Netherlands, Singapore, the United Arab Emirates, and the United Kingdom will continue to collaborate in scaling SAF deployment in their respective markets and regions. Specifically, each has committed to implementing one or more of the policies described in this toolkit where possible.

The SAF Ambassadors group is a core community within the Clean Skies for Tomorrow initiative and will continue to receive its support and guidance through the policy implementation process. An open invitation for other countries to join the SAF Ambassadors group remains, either to share best practices developed through their own experiences or to learn from work already undertaken.

Conclusion

The global aviation industry is at a historical critical juncture. It must make rapid progress in the development and deployment of SAF production pathways before 2030 if it is to have a chance to decarbonize by 2050. The industry has already made significant strides, committing to net zero by 2050. In addition, policy announcements are increasing in scale and will accelerate change, such as the European Union's ReFuelEU proposal, the US Government's economy-wide target of net zero by 2050, and the United Kingdom's net-zero strategy.

But progress depends on resolute action and investment from the entire value chain, which is possible only with a stable policy environment and supportive regulation to enable the business case for investing in SAF production and fostering its demand while assuring high sustainability standards throughout complex value chains.

The CST initiative and the SAF Ambassadors group were founded on the principle of collaborative action. Together, member organizations and governments have aligned on these policy measures as possible mechanisms to help states create the necessary regulatory framework to accelerate the local adoption of SAF and broad global economic decarbonization. Other states are encouraged to join the cause to create the path to cleaner skies for aviation.

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1. Air Transport Action Group, *Waypoint 2050: Balancing Growth in Connectivity with a Comprehensive Global Air Transport Response to the Climate Emergency"*, September 2021, https://aviationbenefits.org/media/167417/w2050_v2021_27sept_full.pdf
2. Clean Skies for Tomorrow, *Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation*, World Economic Forum, 2020, https://www.weforum.org/reports/a356c865-311e-45ca-845d-efe5f762a820
3. Ibid, p.14
4. Kurzawska, P.; Jasinski, R. Overview of Sustainable Aviation Fuels with Emission Characteristic and Particles Emission of the Turbine Engine Fueled ATJ Blends with Different Percentages of ATJ Fuel. Energies 2021, 14, 1858, https://doi.org/10.3390/en14071858
5. International Air Transport Association (IATA), Fact Sheet 2 – Sustainable Aviation Fuel Technical Certifications, n.d., https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-technical-certifications.pdf
6. Clean Skies for Tomorrow, *Deploying Sustainable Aviation Fuels at Scale in India,* World Economic Forum, 2021, https://www.weforum.org/reports/deploying-sustainable-aviation-fuels-at-scale-in-india-a-clean-skies-for-tomorrow-publication
7. International Air Transport Association (IATA), Press Release 66, Net-Zero Carbon Emissions by 2050, 4 October 2021, https://www.iata.org/en/pressroom/2021-releases/2021-10-04-03/
8. International Civil Aviation Organization (ICAO) Environment, *Aviation net zero initiatives and commitments*, 20 September 2021, https://www.icao.int/environmental-protection/SAC/Pages/Aviation-net-zero.aspx
9. The White House, *FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation,* 9 September 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/09/fact-sheet-biden-administration-advances-the-future-of-sustainable-fuels-in-american-aviation/
10. European Commission, *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ensuring a level playing field for sustainable air transport*, 2021, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52021PC0561
11. HM Government, Net Zero Strategy: Build Back Greener, October 2021, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1028157/net-zero-strategy.pdf
12. Aviation Benefits Beyond Borders, Sustainable Aviation Fuel, *Aviation Benefits Beyond Borders*, August 2021, https://aviationbenefits.org/environmental-efficiency/climate-action/sustainable-aviation-fuel/
13. Air Transport Action Group, *Aviation's Energy Transition, Fact Sheet 5,* 2019, https://aviationbenefits.org/downloads/fact-sheet-5-aviations-energy-transition/
14. Ibid
15. Clean Skies for Tomorrow, *Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe*, World Economic Forum, 2021, https://www.weforum.org/reports/guidelines-for-a-sustainable-aviation-fuel-blending-mandate-in-europe
16. International Renewable Energy Agency (IRENA), International Energy Agency (IEA) and REN21, *Renewable Energy Policies in a Time of Transition*, April 2018, https://www.irena.org/publications/2018/apr/renewable-energy-policies-in-a-time-of-transition
17. El-Ashry, M. (2012). National Policies to Promote Renewable Energy. Daedalus, 141(2), 105-110, 2012, http://www.jstor.org/stable/23240283
18. International Renewable Energy Agency (IRENA), *Reaching Zero with Renewables: Biojet fuels*, International Renewable Energy Agency, 2021.
19. Clean Skies for Tomorrow, *Deploying Sustainable Aviation Fuels at Scale in India,* World Economic Forum, 2021, https://www.weforum.org/reports/deploying-sustainable-aviation-fuels-at-scale-in-india-a-clean-skies-for-tomorrow-publication
20. Ministry of Transport, Connecting Singapore, *Oral Reply by Minister for Transport S Iswaran to Parliamentary Question on Sustainable Aviation Fuels and Singapore's Readiness to Participate in the Voluntary Phase of CORSIA*, 3 August 2021, www.mot.gov.sg/news-centre/news/Detail/oral-reply-by-minister-for-transport-s-iswaran-to-parliamentary-question-on-sustainable-aviation-fuels-and-singapore's-readiness-to-participate-in-the-voluntary-phase-of-corsia
21. International Civil Aviation Organization (ICAO), *Kenya Feasibility Study on the use of Sustainable Aviation Fuels*, 2018, https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_Kenya_Report-Web.pdf
22. International Civil Aviation Organization (ICAO), *Burkina Faso, Feasibility Study on the Use of Sustainable Aviation Fuels*, 2018, https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_BurkinaFaso_Report-Web.pdf
23. International Civil Aviation Organization (ICAO), *Capacity Building for CO_2 Mitigation from International Aviation,* 2019, https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg201-206.pdf

24. E4tech and studio Gear Up, *Study on the potential effectiveness of a renewable energy obligation for aviation in the Netherlands*, Ministry of Infrastructure and Water Management of the Netherlands, 2019, https://www.rijksoverheid.nl/documenten/rapporten/2020/03/03/bijlage-1-onderzoek-e4tech-sgu-obligation-for-aviation-in-the-netherlands-final-v3
25. Government of the Netherlands, *Minister Van Nieuwenhuizen imposes use of cleaner fuel in aviation sector,* 15 September 2021, https://www.government.nl/latest/news/2020/03/04/minister-van-nieuwenhuizen-imposes-use-of-cleaner-fuel-in-aviation-sector
26. Fred Ghatala, *Sustainable Aviation Fuel Policy in the United States: A Pragmatic Way Forward*, Atlantic. Council, 2020
27. United Kingdom Government, *Jet Zero Council*, 15 September 2021, https://www.gov.uk/government/groups/jet-zero-council
28. Roundtable on Sustainable Biofuels (RSB), *Decarbonizing Aviation: The Sustainable Way Forward*, Roundtable on Sustainable Biomaterials, June 2020, www.rsb.org/wp-content/uploads/2020/06/RSB-Aviation-Report-WEB_Final.pdf
29. Clean Skies for Tomorrow, *Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation*, World Economic Forum, 2020, p.22, https://www.weforum.org/reports/a356c865-311e-45ca-845d-efe5f762a820
30. Clean Skies for Tomorrow, *Joint Policy Proposal to Accelerate the Deployment of Sustainable Aviation Fuels in Europe,* World Economic Forum, October 2020, https://www.weforum.org/reports/joint-policy-proposal-to-accelerate-the-deployment-of-sustainable-aviation-fuels-in-europe-a-clean-skies-for-tomorrow-publication
31. Energy Transitions Commission, *Bioresources within a Net-Zero Emissions Economy,* 2021
32. Clean Skies for Tomorrow, *Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe*, World Economic Forum, 13 July 2021, https://www.weforum.org/reports/guidelines-for-a-sustainable-aviation-fuel-blending-mandate-in-europe
33. Examples are provided as a proxy and might not exactly match the listed policy.
34. International Renewable Energy Agency (IRENA), *RD&D for Renewable Energy Technologies: Cooperation in Latin America and the Caribbean*, International Renewable Energy Agency, 2015
35. United Kingdom Department for Transport, *Green Fuels, Green Skies (GFGS) competition: shortlisted proposals*, 23 July 2021, https://www.gov.uk/government/publications/green-fuels-green-skies-gfgs-competition/green-fuels-green-skies-gfgs-competition-shortlisted-proposals
36. The White House, *FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation*
37. United Kingdom Department for Business, Energy and Industrial Transport, *Policy Paper: Contracts for Difference*, 2 March 2020, https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference
38. Agora Energiewende, *Making renewable hydrogen cost-competitive: Policy instruments for supporting green* H_2, 2021
39. Pavlenko, N. et al., *The Cost of Supporting Alternative Jet Fuels in the European Union*, International Council on Clean Transportation, ICCT, 2019
40. Netherlands Enterprise Agency, *Stimulation of sustainable energy production and climate transition (SDE++),* 20 September 2021, https://english.rvo.nl/subsidies-programmes/sde
41. International Renewable Energy Agency (IRENA), International Energy Agency (IEA) and REN21, *Renewable Energy Policies in a Time of Transition*, April 2018, https://www.irena.org/publications/2018/apr/renewable-energy-policies-in-a-time-of-transition
42. European Commission, *Combination of financial instruments and grants under shared management funds in the 2021-2027 programming period*, 2021
43. Agora Energiewende, *Making renewable hydrogen cost-competitive: Policy instruments for supporting green* H_2, 2021
44. The White House, *FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation*, 9 September 2021
45. The Brazilian Development Bank (BNDES), *BNDES cria programa com taxa incentivada para estimular redução de emissões de* CO_2 *no setor de combustíveis,* 26 September 2021. https://www.bndes.gov.br/wps/portal/site/home/imprensa/noticias/conteudo/bndes-cria-programa-com-taxa-incentivada-para-estimular%20reduca-de-emissoes%20-de-co2-no-setor-de-combustiveis
46. Material Economics, *EU Biomass Use in a Net-Zero Economy - A Course Correction for EU Biomass*, 2021
47. Runge, *The Case Against More Ethanol: It's Simply Bad for Environment* , 2016, https://e360.yale.edu/features/the_case_against_ethanol_bad_for_environment
48. Renewable fuel plants using the HEFA pathway choose their optimal product slate – for example, SAF vs renewable diesel or other by-products – according to market conditions.
49. Clean Skies for Tomorrow, *Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe*, World Economic Forum, 13 July 2021, https://www.weforum.org/reports/guidelines-for-a-sustainable-aviation-fuel-blending-mandate-in-europe
50. Energy Transitions Commission, *Making Clean Electrification Possible – 30 Years to Electrify the Global Economy,* 2021
51. Ibid.
52. European Commission, *Proposal for amending Regulation (EU) 2019/631 as regards strengthening the* CO_2 *emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition,* 2021, https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf

53. Sorda, G. et al., *An overview of biofuel policies across the world*, 2010, https://www.academia.edu/13656718/An_overview_of_biofuel_policies_across_the_world

54. Clean Skies for Tomorrow, *Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe*, World Economic Forum, 13 July 2021, https://www.weforum.org/reports/guidelines-for-a-sustainable-aviation-fuel-blending-mandate-in-europe

55. Norwegian Government, *More advanced biofuel in aviation,* 26 September 2021, https://www.regjeringen.no/en/aktuelt/mer-avansert-biodrivstoff-i-luftfarten/id2643700/

56. Grantham Research Institute on Climate Change and the Environment, *Do renewable energy technologies need government subsidies?*, 2018, https://www.lse.ac.uk/granthaminstitute/explainers/do-renewable-energy-technologies-need-government-subsidies/

57. Pavlenko, N. et al., *Development and Analysis of a Durable Low-Carbon Fuel Investment Policy for California,* International Council on Clean Transportation, ICCT, 2016

58. Alternative Fuels Data Center, *Second Generation Biofuel Producer Tax Credit,* 26 September 2021, https://afdc.energy.gov/laws/10515

59. Swiss International Air Lines, *CO_2 Offsetting: Why fly with Sustainable Aviation Fuel?* August 2021, https://swiss.compensaid.com/projects/sustainable-aviation-fuel

60. European Commission, *EU Emissions Trading System (EU ETS)*, August 2021, https://ec.europa.eu/clima/policies/ets_en

61. International Renewable Energy Agency (IRENA), *Reaching Zero with Renewables: Biojet fuels*, 2021

62. European Commission, *EU Emissions Trading System (EU ETS),* 2 September 2021, https://ec.europa.eu/clima/policies/ets_en

63. Clean Skies for Tomorrow, *Powering Sustainable Aviation Through Consumer Demand: The Clean Skies for Tomorrow Sustainable Aviation Fuel Certificate (SAFc) Framework*, World Economic Forum, June 2021, https://www.weforum.org/reports/powering-sustainable-aviation-through-consumer-demand-the-clean-skies-for-tomorrow-sustainable-aviation-fuel-certificate-safc-framework

64. Agora Energiewende, *Making renewable hydrogen cost-competitive: Policy instruments for supporting green H_2*, 2021

65. Based on discussions with the Dutch Ministry of Infrastructure and Water Management.

66. Clean Skies for Tomorrow, *Powering Sustainable Aviation Through Consumer Demand: The Clean Skies for Tomorrow Sustainable Aviation Fuel Certificate (SAFc) Framework*, World Economic Forum, June 2021, https://www.weforum.org/reports/powering-sustainable-aviation-through-consumer-demand-the-clean-skies-for-tomorrow-sustainable-aviation-fuel-certificate-safc-framework

67. Ibid

68. KLM *SAF Corporate Traveler*, Lufthansa Compensaid, SAS, etc.

69. US Environmental Protection Agency, *User's Guide for the EPA Moderated Transaction System (EMTS)*, 2020, https://www.epa.gov/fuels-registration-reporting-and-compliance-help/users-guide-epa-moderated-transaction-system-emts

70. Kojima, Masami et al., *Considering Trade Policies for Liquid Biofuels: ESMAP Renewable Energy Special Report 004/07*, 2007

71. Argus Media, *Asia's RCEP trade deal to remove biofuel tariffs, 16 November 2020,* https://www.argusmedia.com/en/news/2160185-asias-rcep-trade-deal-to-remove-biofuel-tariffs

72. Clean Skies for Tomorrow, *Joint Policy Proposal to Accelerate the Deployment of Sustainable Aviation Fuels in Europe,* World Economic Forum, October 2020, https://www.weforum.org/reports/joint-policy-proposal-to-accelerate-the-deployment-of-sustainable-aviation-fuels-in-europe-a-clean-skies-for-tomorrow-publication

73. Clean Skies for Tomorrow, *Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation*, World Economic Forum, 2020, https://www.weforum.org/reports/a356c865-311e-45ca-845d-efe5f762a820

74. Ibid

75. International Civil Aviation Organization (ICAO), *ICAO "solar-at-gate" pilot project for the reduction of CO_2 emissions of aircraft during ground operations launched in Kenya*, 14, December 2018, https://www.icao.int/Newsroom/Pages/ICAO-solar-at-gate-pilot-project-for-the-reduction-of-CO2-emissions-of-aircraft-during-ground-operations-launched-in-Kenya.aspx

76. Agora Energiewende, *Making renewable hydrogen cost-competitive: Policy instruments for supporting green H_2*, 2021

77. Clean Skies for Tomorrow, *Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe*, World Economic Forum, 13 July 2021, https://www.weforum.org/reports/guidelines-for-a-sustainable-aviation-fuel-blending-mandate-in-europe

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