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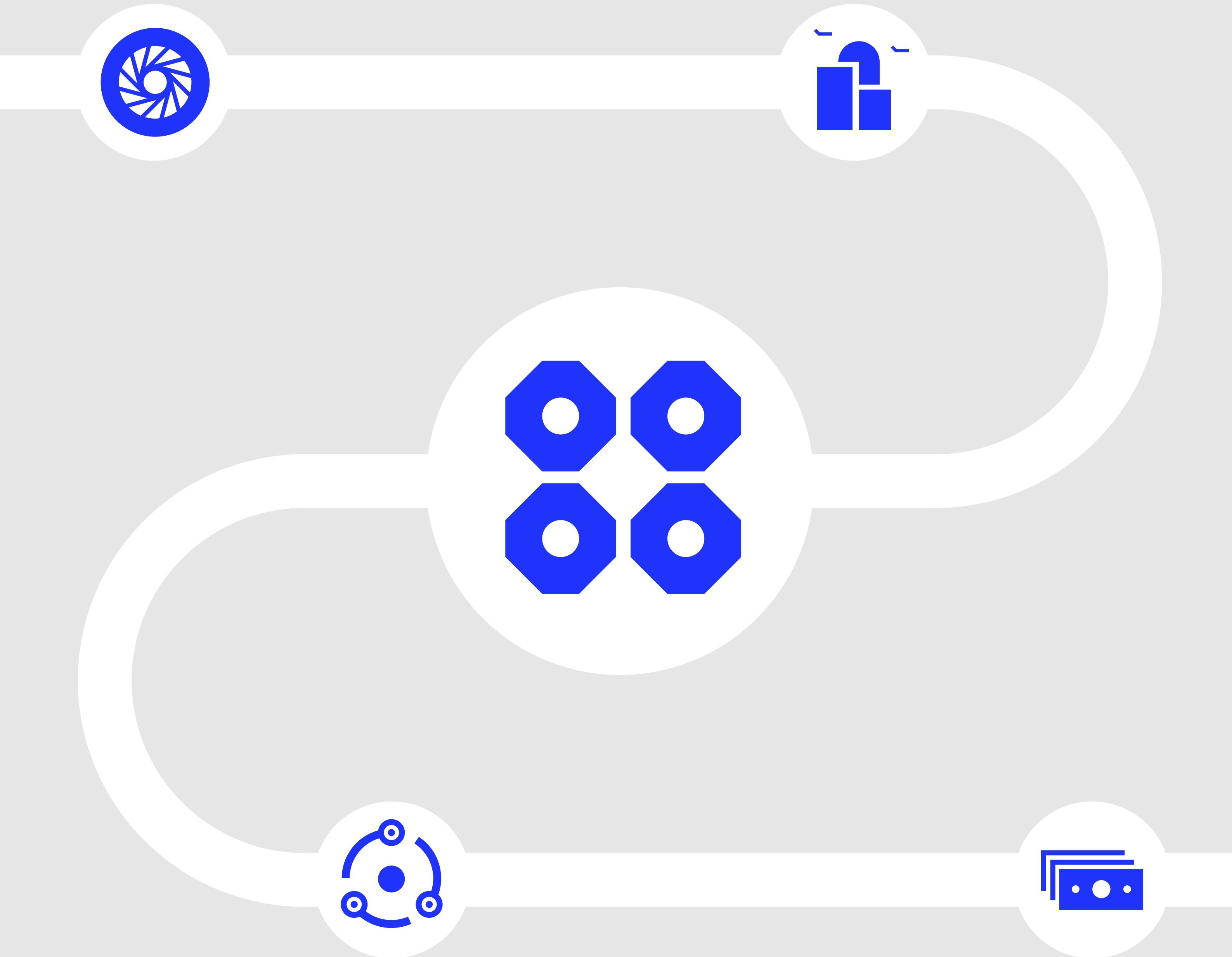
Policy
Net Zero CO_2 Emissions Roadmap

IATA Sustainability and Economics



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Contents

Glossary

ART
Architecture for REDD+ Transactions

ASTM
American Society for Testing and Materials

AtJ
Alcohol-to-Jet

BECCS
Bioenergy with Carbon Capture and Storage

BOLR
Buyer of Last Resort

CAPEX
Capital Expenditures

CAAF/3
Third Conference on Aviation Alternative Fuels

CDR
Carbon Dioxide Removals

CfD
Contracts for Difference

CORSIA
Carbon Offsetting and Reduction Scheme for International Aviation

COP
Conference of the Parties

CO_2
Carbon Dioxide

DAC
Direct Air Capture

DOC
Direct Ocean Capture

DOE
Department of Energy

EEUs
Eligible Emissions Units

EIS
Entry into Service

EU ETS
European Union Emissions Trading System

EU RED
European Union Renewable Energy Directive

FAST
Fueling Aviation's Sustainable Transition

FT
Fischer-Tropsch

GBP
Great British Pound

GDP
Gross Domestic Product

HEFA
Hydro processed Esters and Fatty Acids

ICAO
International Civil Aviation Organization

IPCC
International Panel on Climate Change

LCAF
Lower Carbon Aviation Fuels

LoA
Letter of Authorization

Mt
Million tonnes

NDCs
Nationally Determined Contributions

OPEX
Operational Expenditures

POS
Proof of Sustainability

PtL
Power-to-Liquid

PPPs
Public-Private Partnerships

REDD
Reducing Emissions from Deforestation and forest Degradation

RFNBO
Renewable Fuels of Non-Biological Origin

SAF
Sustainable Aviation Fuel

SDGs
Sustainable Development Goals

UNFCCC
United Nations Framework Convention on Climate Change

USD
United States Dollar

Table of figures

Boxes

Charts

Map

Table

Executive summary

The Paris Agreement, signed by as many as 195 Parties to the Convention, adopted the long-term goal of keeping the rise in global surface temperature to well below 2° Celsius above pre-industrial levels. The airline industry supports this long-term goal and is committed to achieving net zero CO_2 emissions from air transportation by 2050. The efforts of airlines and their partners in this context cannot be analyzed as a transportation issue. Air transportation's energy transition is part of the global energy transition and the Paris Agreement's mission to limit global warming.

This roadmap presents a menu for policymakers to consider in the context of accelerating the air transport industry's transition to net zero CO_2 emissions from now to 2050. The role of effective policymaking in this transition can hardly be exaggerated—it holds the key to success in all endeavors, from Research & Development (R&D) to commercialization of new technologies, from nascent markets to globally well-balanced supply and demand, and of course, from using fossil fuels to renewable energy sources in global aviation.

The policy menu is articulated over three different time periods—immediate, mid-term, and long-term—and addresses the order in which to target different objectives and how to tailor policy measures to these. The objectives to be prioritized include:

Immediate policy objectives (until end 2025)

The first phase focuses on urgent actions necessary to kickstart the transition.

1. **Unlock CORSIA Eligible Emissions Units (EEUs):** To maximize CO_2 emission reductions under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), States must unlock sufficient quantities of Eligible Emissions Units.

2. **Prioritize Sustainable Aviation Fuel (SAF) in refinery output:** Increasing the share of SAF production in the product mix of existing renewable fuel production facilities, including co-processing in conventional refineries, is essential for supply to meet near-term demand.

3. **Attract investment for SAF production and new propulsion technologies:** The scaling up of SAF production and advancing new propulsion technologies like hydrogen require significant investment, and policy is needed to help reallocate capital flows more in favor of these.

4. **Ensure environmental integrity of offsetting credits and aviation cleaner energies:** Establishing robust standards for offsets and alternative fuels' environmental and sustainability credentials is indispensable for proper tracking and verification so that obligations can be met.

5. **Build a SAF accounting framework:** Developing a robust chain of custody for SAF is essential to maintaining transparency, traceability, and trust in accounting for CO_2 emission reductions from SAF.

6. **Promote global, liquid, and transparent cleaner aviation energy markets:** Nurture the nascent new energy markets so they develop into global, liquid, and transparent markets where competition is healthy and where new entrants and innovation can flourish.

Mid-term policy objectives (2026-2030)

This phase addresses the need to eliminate existing barriers and to drive diversification and scale-up of aviation cleaner energies. The essential role of enhanced R&D in carbon removal technologies remains a priority over this time horizon.

1. **Eliminate barriers to SAF distribution and use:** Addressing gaps in infrastructure and lack of harmonized and supportive regulation will facilitate the widespread adoption of SAF.

2. **Drive diversification and scale-up of aviation cleaner energies:** The diversification of aviation cleaner energies through the promotion of a wide variety of feedstock and production pathways will ensure future resilience and scalability.

3. **Enhance R&D in carbon dioxide removal technologies:** Investing in research and development of innovative carbon capture and removal technologies is a must, as all levers will be needed to deliver air transportation's decarbonization.

Long-term policy objectives (2031-2050)

The final phase focuses on sustaining innovation in SAF and new propulsion technologies. This is also when the importance of periodic policy reviews will come to the fore.

1. **Conduct periodic policy reviews:** Regular assessments of the effectiveness of the policies adopted will help guide future policy adjustments and ensure alignment with technological advancements and environmental goals.

2. **Foster innovation in non-biological SAF:** Supporting continuous innovation in non-biological SAF is imperative to expand fuel options, as no single technology will suffice to satisfy the needs of the air transport industry's decarbonization.

3. **Adopt new propulsion technologies:** Enabling and capitalizing on advancements in propulsion technologies is a further requirement for air transportation's energy transition.

As of now, the policy measures that countries have put in place are insufficient to secure the transition. It is impossible today for airlines to meet the obligations that they have been subjected to, and airlines are of course much less able to deliver on the net zero CO_2 emissions objective by 2050, as things currently stand.

Policymakers need to assimilate that air transportation's energy transition is not a transportation issue—it is an economic development issue and an integral part of the global response to climate change. They also need to make some bold moves; the most urgent and arguably the most effective of all would be to remove the fossil fuel exploration and production subsidies provided to corporations in the oil and gas sector and reallocate them to the activity that the world is seeking to promote—the production of renewable energy and SAF. That would send a powerful signal for the private sector to follow and eliminate much ambiguity about the direction of policy.

The policy measures, the sums of finance, and even the time horizon available to achieve this challenge are all tried and tested and proven to be effective and feasible—this is the lesson learned from the experiences of creating the new markets of solar and wind energy.

The costs associated with the energy transition are indisputable. For the air transport industry, the total annual transition costs are expected to increase significantly from USD 0.12 billion in 2023 to USD 19 billion in 2030, reaching USD 744 billion in 2050.[1] Policy will have to help bring this cost down. Similarly, the capital investments needed for the transition can be reduced by half and more if policy intervenes in specific areas and in a concerted manner. With radical collaboration and unity of purpose, it will be entirely feasible to deliver air transportation's energy transition, in the interest of a global economy where growth is inclusive, sustainable, and delivering better outcomes for all.

1 IATA (2024), Net Zero CO_2 Emissions Finance Roadmap.

1. Overview

Airlines are committed to reaching net zero CO_2 emissions by 2050 and to meeting the obligations that the industry is subject to along this path. In 2023, IATA published its vision of the levers needed to make net zero CO_2 emissions for air transportation a reality as a set of five roadmaps covering aircraft technology, energy infrastructure, operations, fuel, finance, and policy.[2] This document expands upon and updates the policy roadmap.

The roadmaps detail milestones that need to be achieved over the essentially five years to 2030, the year for which the International Civil Aviation Organization (ICAO) established the CAAF/3 collective vision, and the 25 years remaining to 2050. There is no time to lose.

Governments, and all parts of government, must help ensure that all the levers necessary in air transportation's energy transition can be employed to their full potential and that the means for our sector to meet its obligations are available. Therefore, policies should be targeted to create and accelerate the development of the requisite new markets and ensure they can perform their necessary functions.

This roadmap provides a chronological "menu" of policy options to facilitate the air transport industry's journey towards net zero CO_2 emissions. While there is no "one-size-fits-all" set of policies that will guarantee more sustainable flights at the same time everywhere, there are policy objectives that have widespread applicability across jurisdictions and timeframes that underpin the recommendations detailed in this roadmap. Specific policy measures are also discussed, and these are likely to be more relevant in certain geographic locations than others and address different market contexts.

The Policy Roadmap is articulated over three-time horizons: immediate policy objectives (until the end of 2025), medium-term policy objectives (2026-2030), and long-term policy objectives (2031-2050). Before detailing these, we first turn to the policy characteristics that can be considered best practices in light of past experiences with creating new energy markets.

2 IATA (2023). Net Zero Roadmaps.

2. Effective policymaking for aviation's energy transition: best practices

Policymaking is a multidimensional endeavor that involves stating clear policy objectives over specific timelines. Each lever that can be used in air transportation's energy transition must be used to the fullest to achieve net zero CO_2 emissions by 2050. The policy instruments, the mix and intensity of such instruments, and the sequencing of their implementation will all be contingent upon the technology type, its stage of development, the capacity of the respective value chains to scale up sufficiently, as well as country- or region-specific factors. Moreover, air transport's decarbonization is not an issue that can be solved by the transportation sector alone. This challenge requires an entirely new form of cross-governmental and cross-industry problem-solving that we label "radical collaboration". Air transportation's decarbonization is integral to and depends on the world economy's energy transition and needs to be addressed as part of national, regional, and global priorities.

Within that complex matrix of moving parts, there is a set of characteristics that is often shared across successful policymaking experiences, and that can be thought of as best practices. With respect to air transportation's energy transition, we note the following:

Clarity of purpose	Create an energy policy framework that states policy objectives clearly and within a specific timeframe, and that is tailored to local conditions as well as supported by international cooperation.
Stability and predictability	Policies need to be stable and predictable to allow economic actors sufficient certainty and foster investments.
Harmonization	The harmonization of all rules and regulations, such as sustainability criteria, certification requirements, reporting and accounting rules, across government initiatives, across countries and regions, and as far as possible globally, greatly facilitates innovation and market development.
Strategic sequencing	Strategic sequencing aims to optimize outcomes over the target horizon and generally involves leading with technology-push policies, followed by demand-pull measures and market-based policies as technologies mature (Box 1).
Technology-neutral and feedstock-agnostic	Policy should be technology-neutral and feedstock agnostic to avoid taking early bets on immature solutions. This promotes the diversification and multiplication of production pathways and feedstock supply chains and fosters competition.
Review mechanism	Incorporate periodic reviews to ensure that policy remains fit for purpose and to address any unintended consequences in a timely manner. "Exit" strategies need to be considered for when markets are mature enough.

Box 1: What is policy sequencing?

Policy design must consider both the order and the magnitude of the instruments to be used to obtain a desired outcome over a specific period. Policy sequencing refers to how to implement policy over time and which policy instrument to use when.[3]

There are two types of policy sequencing—strategic and reactive:

1. Strategic policy sequencing emphasizes the importance of understanding the policy mix, the interactions between policies, and how to get the most out of each action over the stated period. Often, there are multiple policy goals, and these are unlikely to be attainable with a single policy instrument. Strategic policy sequencing generally involves technology-push policies as a critical first step. Such policies can lower the costs of new technologies rapidly, broaden their political support, and render subsequent demand-pull policies more effective and less distortive. This, in turn, helps address potential economic and cultural barriers more swiftly.[4]
2. In the absence of strategic policy sequencing, policy formulation becomes reactive, focusing on certain key bottlenecks and aiming to resolve them by developing an improved regulatory and legal framework.[5]

More information and illustrations of the impact of policy sequencing on the creation of specific energy markets are available in IATA's recent publication on the topic.[6]

3 Pakizer, K., Lieberherr, E., Farrelly, M., Bach, P.M., Saurí, D., March, H., Hacker, M. and Binz, C. (2023). Policy sequencing for early-stage transition dynamics – A process model and comparative case study in the water sector. Environmental Innovation and Societal Transitions, [online] 48, p.100730.
4 Ibid.
5 Ibid.
6 IATA (2024). A reflection on policies used to support the creation of new renewable energy markets Lessons for aviation?

3. Net Zero CO_2 Emissions Policy Roadmap

Immediate policy action until end of 2025

- Unlock market for CORSIA EEUs
- Harmonize ICAO and UNFCCC climate change frameworks
- Implement technology-agnostic policy frameworks for carbon removal solutions
- Repurpose existing financial resources to support SAF production
- Shift existing biofuel production capacity to SAF
- Encourage co-processing
- Implement coordinated demand-pull and technology-push SAF policies
- Ensure incentives have realistic duration
- Promote global, liquid, and transparent SAF markets
- Increase demand for SAF through governmental commitments
- Ensure SAF policy mixes are technology and feedstock agnostic
- Adopt globally harmonized SAF accounting framework

Mid-term policy action 2026–2030

- Enable access to incumbent fuel infrastructure to SAF
- Ramp-up SAF production from non-biological feedstock
- Facilitate dual conformance in SAF sustainability certification
- Adopt globally harmonized sustainability criteria for offsets and alternative fuels
- Attract investments into SAF and new propulsion technologies

2030 WAYPOINT
CAAF/3's Collective Global Aspirational Vision

Long-term policy action 2031–2050

WAYPOINT
Entry into service of zero-carbon aircraft

- Foster continuous innovation in non-biological SAF
- Adopt globally harmonized refueling standards for new propulsion aircraft

2035 WAYPOINT
Review CORSIA and role of offsets

- Develop airworthiness standards and certification process for hydrogen flights
- Drive diversification of all aviation cleaner energies
- Support development of new propulsion technologies
- Support development of new fueling infrastructure for hydrogen aircraft
- Periodically review and assess incumbent policies
- Adopt a standardized CO_2 emissions tracking and reporting methodology

Net Zero CO_2 Emissions

Offsets/ Removals

SAF

New Technology

Tracking and Review

IATA

3.1 Immediate policy objectives: Until end 2025

The policy priorities that need to be addressed immediately and without further delay are discussed below. For each policy objective, the Policy Roadmap identifies concrete but non-exhaustive actions that policymakers could take.

Before diving into these actions, we acknowledge that all policy options presented are subject to budget considerations. Government funds are limited, and their allocation must be part of the government's strategy, within which many essential priorities compete for limited resources. Regarding funding the policy recommendations that would enable and accelerate air transportation's energy transition, policymakers should first and foremost allocate the funds collected from existing aviation sustainability-related mechanisms and other levies impacting the industry to air transportation's decarbonization programs. We note sources of funds (Box 2) that are levied on air transportation and that are allocated, or planned to be allocated, to the air transport industry's decarbonization efforts.

Box 2: The funds levied on air transportation should be allocated to drive the industry's decarbonization

Identifying the optimal source of funding is necessary to allow policymakers to implement the policy actions that pave the way for the air transport industry's journey toward net zero CO_2 emissions.

Under established mechanisms, it is worth noting:

- **20 million free allowances under EU ETS to incentivize the use of SAF.** The European Union has introduced the SAF Allowances fund, making 20 million free allowances available from 2024 to 2030 to cover the price differential between SAF and fossil-based jet fuel. The SAF allowances will be awarded on a first-come, first-served basis to incentivize first movers to use SAF.

- **Singapore's innovative use of a levy to fund SAF purchases.** Singapore will introduce a SAF levy starting in 2026. The purpose of the levy is to finance the use of 1% SAF in total fuel consumption from 2026, rising to 3-5% by 2030, subject to global developments and the availability of SAF. Further details will be provided in 2025, allowing time for industry and travelers to prepare.

- **Revenue under UK ETS is a potential source of funding for the UK SAF Revenue Certainty Mechanism.** As the UK government ponders a UK SAF Revenue Certainty Mechanism, it could allocate revenue from the UK ETS for this purpose. This has been done successfully in the maritime sector, where shipping-related ETS revenue is used to fund Contracts for Difference to incentivize private investment in the production and use of scalable zero CO_2 emission fuels.[7] In air transportation, a first step could be to use the free allocations that are designed to phase out from 2026.

7 Globalmaritimeforum.org (2022). How EU Contracts for Difference can support zero-emission fuels.

Objective #1: Unlock CORSIA EEUs

Airlines are required to offset CO_2 emissions under CORSIA[8] as of 1 January 2024. It is estimated that CORSIA will result in between 1.2 and 2 billion tonnes[9] of CO_2 emissions reductions between now and 2035.[10] The carbon offset credits that meet certain criteria defined by ICAO are called Eligible Emissions Units (EEUs). The EEUs are calculated to equate to one tonne of CO_2 emissions generated through emissions-reducing programs that comply with the strict eligibility criteria approved by ICAO. At the same time, the host countries[11] must authorize the usage of those units for the purpose of CORSIA by issuing a Letter of Authorization (LoA) and must conduct a corresponding adjustment in the national registry under their Nationally Determined Contributions (NDCs) that States submit under the UNFCCC Paris Agreement.[12] Essentially, the LoA and the subsequent corresponding adjustment ensure that the emissions reductions from the EEUs claimed by airlines are not double claimed by the host countries.

Prior to February 2024, not a single host country had released any EEUs by conducting the corresponding adjustments as required by CORSIA, and consequently, CORSIA EEUs were not available in the carbon market. This renders immediate compliance impossible for airlines. Moreover, the lack of supply of EEUs tends to increase the overall cost to airlines, arguably making decarbonization efforts outside of CORSIA more difficult. Some host countries lack awareness of CORSIA and the requirement to release carbon credits to air transportation, and some countries lack the institutional infrastructure (e.g., the national registry for NDCs) to conduct corresponding adjustments.

Furthermore, this compliance requirement must not be taken as an opportunity to raise additional revenue streams from airlines—such considerations must be kept separate. The mixing of policy objectives in this context, i.e., enable airlines to comply with regulation, and raise funds for other, not specified, purposes, can be severely distortionary and produce negative results. States should refrain from charging for issuing the LoAs that the same States have stipulated that airlines must obtain for compliance purposes. States should also refrain from adding in any way shape or form to the costs of the EEUs, the price of which is already distorted by the lack of supply as States delay their arrival on the market.

Immediate policy actions could include:

- At the national level, the necessary **infrastructure for issuing LoAs and conducting corresponding adjustments must be provided**. And the pace of releasing credits to the market must be accelerated.
- As the issuance of LoAs is a **compliance requirement** under ICAO and CORSIA, which Member States have agreed to, States should refrain from charging airlines for this document and should also refrain from imposing any additional costs to the price of the EEUs.
- At the international level, **an awareness exercise and policy harmonization effort** between ICAO and UNFCCC would be an important immediate step towards unlocking the market availability of CORSIA EEUs.

Objective #2: Increase the share of SAF in renewable fuel facilities' product mix

ICAO's third Conference on Aviation Alternative Fuels, CAAF/3, expressed a collective vision for reducing the air transportation industry's CO_2 emissions through cleaner energies by 2030. The meeting adopted a non-binding objective to decrease the carbon intensity of fuels used in international aviation by 5% by 2030 through the use of SAF, Lower Carbon Aviation Fuels (LCAF), and other aviation cleaner energies as part of the Declaration within an overarching "ICAO Global Framework for aviation cleaner energies".[14] This waypoint underscores the critical significance and urgent need for policymakers to advance effective policy options that incentivize and stimulate a sharp increase in SAF production.

IATA estimates that the 5% carbon intensity reduction target in international aviation alone would require around 14 million tonnes (Mt) of SAF by 2030.[15] Including domestic traffic, the required SAF volume grows to 24 Mt by 2030. Global SAF output was 0.5 Mt in 2023 and will likely reach 1.5 Mt in 2024. SAF production must increase by a factor of 16 within this short space of time to meet demand. This will not happen unless the public sector mobilizes swift, strong, and effective support policies. As for the certainty of demand, at the time of writing, 50 airlines representing 40% of global air traffic have pledged to use a 5% SAF blend or higher in their operations by 2030, representing about 13 Mt of SAF demand by that year.

To produce 24 Mt of SAF by 2030, a minimum of about 100 new renewable fuel plants would need to be operational by then.[16] This number assumes that the SAF share in each biorefinery's product mix is maximized per production pathway. On the 2050 horizon, a total of 3,400 new renewable fuel plants would be needed to produce enough SAF to meet air transportation's demand, if the SAF share of their output is maximized.[17] A lower SAF chare of each refinery's output would require additional biorefineries to be built.

8 CORSIA is the Carbon Offsetting and Reduction Scheme for International Aviation. It is the first global market-based measure for any sector and represents a cooperative approach that moves away from a "patchwork" of national or regional regulatory initiatives.
9 IATA writes US English; however, with respect to references to units of 1,000 kilograms, we write tonne, and not ton.
10 IATA (2024). CORSIA Fact sheet.
11 Host countries are countries where the emission unit originates.
12 United Nations Framework Convention on Climate Change (UNFCCC).
13 ICAO Document CORSIA Emissions Unit Eligibility Criteria states: "In order to prevent double claiming, eligible programs should require and demonstrate that host countries of emissions reduction activities agree to account for any offset units issued as a result of those activities such that double claiming does not occur between the airline and the host country of the emissions reduction activity".
14 ICAO Global Framework for SAF, LCAF and other Aviation Cleaner Energies.
15 With the assumption of a reasonably high average emissions reduction factor of between 75% and 85%.
16 IATA (2024), Net Zero CO_2 Emissions Finance Roadmap.
17 Assuming maximum theoretical SAF yields.

Different regions of the world will contribute to ramping up SAF supply in accordance with their respective feedstock availability and maturity of clean aviation-fuel industries. Nevertheless, the opportunity that building feedstock and SAF industries represents across nearly all countries is unparalleled. As an economic development strategy, it can generate wide social and economic benefits. These are not limited to new jobs across industry, agriculture, and elsewhere but can include increased energy availability, security, and independence, and can drive exports, deal with waste, improve natural habitats, and much more. Promoting sustainable aviation must be at the top of any government's agenda as a key enabler of economic development, over and above the importance of the air transport industry's direct contributions to the economy and society.

Air transportation's need for SAF should be understood in each country's total renewable energy production and consumption context. Existing and future renewable fuel production should adapt to the growing demand for SAF and the waning demand for biofuel for road transportation. All refineries produce a mix of products, and the production of fuel for aircraft competes with other distillates, such as diesel, in terms of its share of total refined output. Policy can help skew the product optimization process at the refinery more in favor of SAF. This is even more justified as the demand for fuels used in road transportation is reduced by the swift transition to electric and hybrid propulsion systems.

Immediate policy actions could include:

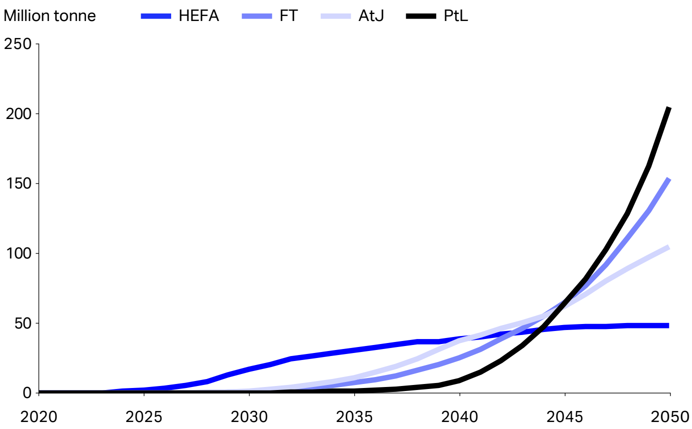
- **SAF blender/production tax credits:** Tax credits can address the economic disadvantage of SAF production at the biorefinery. The value of SAF tax credits should be higher than that enjoyed by renewable diesel.

- **Revenue Certainty Mechanism:** A Revenue Certainty Mechanism provides some degree of price certainty to SAF producers, which improves the investment case and enhances the chance to secure the capital needed.

- **Streamline the regulatory requirements regarding co-processing of SAF:** Enabling the co-processing of bio-oils with petroleum crudes in existing petroleum refineries immediately increases SAF production. It requires limited capital expenditure, if any, in most existing refineries (Box 3). Policies must be put in place to facilitate the standardization of the allocation of environmental attributes to co-processed fuel without imposing additional testing requirements.

- **No HEFA cap under SAF mandates:** While acknowledging the need to diversify SAF production in the mid- and long-term, it is expected that the overwhelming majority of the SAF volume over the next five years will be derived from HEFA (Chart 1). Governments should refrain from capping the HEFA pathway under a SAF mandate (Box 4) to allow airlines to take full advantage of the immediate readiness of HEFA SAF production.

Chart 1: SAF production output by pathway, 2020-2050, million tonne



Source: IATA Sustainability and Economics

Box 3: The role of co-processed SAF in aviation's energy transition: An accelerator

Co-processing involves the use of renewable feedstock in conventional fossil-fuel refining units. This allows existing refineries to integrate renewable feedstocks into the production processes without the need for extensive infrastructural changes, nor of course the need to build a refinery from scratch. It is possible, as of today, to co-process 5% approved renewable feedstocks with petroleum crude and meet the requirements of the industry jet fuel standard ASTM D1655.[18]

Assessments are underway to increase the 5% limit to 30%. Higher blends could require more extensive refinery modifications, though some refineries will be able to boost SAF production quickly with only minor modifications. Regardless of the design and operational modifications required to facilitate higher limits, the overall cost will be lower and the time to operationalize will be greatly reduced compared to building a standalone renewable fuel facility. With supportive policies and, importantly, a simplified regulatory approach to track renewable content, co-processing can play an important role in aviation's energy transition.

The speed with which co-processing can generate significant volumes of fuel will of course depend on how fast the required biogenic feedstocks can be produced. Policies aimed at feedstock rationalization and expanding new feedstocks will be key for how effectively this bridging solution can contribute to air transport industry's decarbonization.

18 ASTM International, formerly known as American Society for Testing and Materials, is a standards organization that develops and publishes voluntary consensus technical international standards for a wide range of materials, products, systems, and services. Some 12,575 apply globally. D1655 defines the specific types of aviation fuel for civil use: Jet A; and Jet A-1, and states that "The fuels shall be sampled and tested appropriately to examine their conformance to detailed requirements as to composition, volatility, fluidity, combustion, corrosion, thermal stability, contaminants, and additives".

Box 4: SAF mandates should not be imposed in isolation

Several countries have implemented SAF mandates, which are State-imposed obligations to produce or use a specified share of SAF in total jet fuel production or consumption. Mandates are currently imposed upon fuel suppliers. For instance, the Refuel EU aviation initiative put an obligation on aviation fuel suppliers to ensure that all fuel made available to aircraft operators at EU airports contains a minimum share of SAF from 2025 and, from 2030, a minimum share of synthetic fuels, with both shares increasing progressively until 2050. Fuel suppliers will have to incorporate 2% SAF in 2025, 6% in 2030, and 70% in 2050. From 2030, 1.2% of fuels must also be synthetic fuels, rising to 35% in 2050.[19]

Mandates targeted at fuel suppliers will logically increase production. However, if penalties for non-compliance are light, production might not increase, and the cost of penalties can be transferred to the airlines, who would end up paying more for traditional jet fuel without benefiting from any reduction in CO_2 emissions. Moreover, mandates tend to "cartelize" the market, offering protection to incumbents and existing technologies while discouraging innovation and new entrants. To mitigate the undesirable anti-competition consequences of mandates, the obligation could be pushed upstream from fuel suppliers to fuel producers.

Mandates imposed upon customers will be counterproductive if the supply of the product is limited. In such cases, it would only make a scarce product even rarer and drive up its price.

Should policymakers nevertheless wish to impose mandates, it is essential that their introduction is programmed as part of an overall energy policy and that it is sequenced to follow the creation of necessary market infrastructure. That should include strong R&D support to ensure continued innovation, and protection of new entrants and of consumers against incumbent producers' potentially outsized pricing power. In other words, technology-push policy instruments are needed to accelerate the development and subsequent commercial viability of new solutions, whether these are coupled with mandates or not, and mandates should not be used in isolation.

Objective #3: Attract investment to scale up SAF production and mature new propulsion technologies

There are many reasons why investments in novel technologies that involve the creation of entirely new markets are the reserve of only the most risk-tolerant investors, and these investors are scarce. A further challenge is that the investment case in the energy sector is so overwhelmingly skewed in favor of fossil fuels. Policymakers must play an active role in readjusting the investment proposition more in favor of renewable energies, and in favor of SAF. They must also realize that private money will always follow public money, and governments must show the way.

The capital investment needed to build the new biorefineries in our immediate- and mid-term transition period (i.e., 2024-2030) is around USD 74 billion.[20] This would allow supply to meet air transportation's demand in 2030, provided that the SAF share is maximized in these facilities' output mix. In 2050, the cumulative investment requirement over the entire transition period climbs to USD 4.2 trillion for an estimated 3,400 operational renewable fuel plants, based on the same high SAF share of refined output assumption.

When assessing the magnitude of these investment needs, it is important to understand that these numbers refer to the refinery whose installation will produce renewable fuel for uses other than aviation. Air transportation's shares of these totals are 60% and 51% on the 2030 and the 2050 horizon, respectively.

Governments need to redirect public funds to lead the necessary investments in new biorefineries, and they need to enable the private sector to follow by implementing seminally important policy changes and enhanced support measures.

19 European Council – Council of the European Union (2023). Press corner. ReFuelEU Aviation initiative: Council adopts new law to decarbonize the aviation sector.
20 IATA (2024). Net Zero CO_2 Emissions Finance Roadmap.

Immediate policy actions could include:

- **The removal of subsidies for fossil fuel exploration and production:** The current policy impetus is in stark contrast to the world's objective of phasing out fossil fuels as expressed by the Paris Agreement and subsequent commitments. The subsidizing of fossil fuel exploration and production attracts capital to this activity and draws it away from other forms of energy production. Maintaining these subsidies has an effect comparable to imposing a tax on renewable energy production (Box 5). Clearly, what is needed is the exact opposite, e.g., an urgent reallocation of these subsidies to the activity that the world is seeking to promote—the production of renewable energy and SAF.

- **Public-private partnerships (PPPs)** can take various forms and allow risks and rewards related to the project to be mutualized and shared across stakeholders. Examples of public-private partnerships in SAF production and in next-generation aircraft technology include:

  The EU Clean Aviation Initiative[21] established in 2021, is a PPP between the European Commission and the European aerospace to achieve its environmental performance targets. The initiative aims to:

  – Unite expertise, capacities, and resources across the key stakeholders of the aviation industry to agree and align the strategy towards sustainable aviation.

  – Enable investments that can only be realized through consolidated efforts.

  – Accelerate development thanks to public sector co-financing. For instance, in September 2023, the Governing Board of the Clean Aviation Joint Undertaking approved EUR 380 million, including EUR 152 million in EU funding, for an additional eight projects accelerating aviation's trajectory towards net zero CO_2 emissions, in support of the European Green Deal.[22]

  The UK Jet Zero Council is a PPP that promotes the deployment of SAF and zero-emission flights.[23] It is a partnership between industry, academia, and the UK government to bring together ministers and chief executive officer-level stakeholders, with the aim to deliver at least 10% SAF in the UK fuel mix by 2030 and zero CO_2 emission transatlantic flight within a generation. The Council seeks to drive the ambitious delivery of new technologies and innovative ways to cut CO_2 aviation emissions. The objectives of the UK Jet Zero Council are to:

  – Provide leadership for achieving net zero CO_2 emissions in air transportation in the UK.

  – Identify and maximize the benefits of developing the aviation sector in the UK and address industry challenges.

  – Accelerate the development and operation of zero CO_2 emission aircraft and systems through investment and cross-sector collaboration.

  – Speed up the production of SAF by supporting investment, R&D, and cost reduction.

  – Support grassroot innovation to make the UK a leading hub for new aviation technology.

  – Involve disruptors and innovators to challenge and improve existing approaches.

  The Japanese Public-private SAF Council was established in April 2022 to promote the development, production, and use of sustainable aviation fuels in Japan. The council brings together stakeholders from both the public and private sectors, including government agencies, airlines, fuel producers, and research institutions. Its primary role is to coordinate efforts to reduce CO_2 emissions in the air transport industry, support the commercialization of SAF, and help Japan achieve its CO_2 neutrality goals by 2050. The council also works on creating policies and frameworks to facilitate the scaling up of SAF production and usage. As a result of this collaborative approach, the Japanese government plans to set a target for SAF supply by 2030 under Japan's "Sophisticated Methods of Energy Supply Structures Act", with a draft notice expected in the autumn of 2024.

- **Two-way Contracts for Difference (CfD):** These involve a technology provider (e.g., a SAF producer) who commits to produce an agreed volume of output, and the counterparty (generally a State entity) provides a price guarantee which comes into effect if the market price falls below a pre-determined strike price. In that case, the technology provider receives the difference, while if the market price is above the strike price, the provider is required to pay back the difference to the State.[24] CfDs provide a degree of certainty for the producer, which improves the investment case and helps raise the capital needed for the investment. This type of revenue certainty can also contribute to overall price stability and, in turn, bring about greater transparency and maturity of nascent markets.

- **Buyer of last resort (BOLR)** facilities provide producers with a minimum price for every tonne of SAF produced without giving any additional return to equity investors. BOLR can be viewed as a simple alternative to CfDs, though potentially at a greater cost to the BOLR entity.

21 Clean-aviation.eu (2022). Home | Clean Aviation.
22 Clean-aviation.eu (2023). €380 million for 8 new daring Clean Aviation projects to pave the way for highly efficient aircraft.
23 Gov.uk (n.d.). Jet Zero Council.
24 European Commission (2024). Press corner.

Direct financing is needed for capital expenditures (capex),[25] operational expenditures (opex),[26] and SAF feedstock costs.[27] Over time, the nature of the financing need will adjust to evolving market and technological maturities, and private capital can play an increasingly important role. Various direct financial initiatives can be implemented, including:

- **Grants** for R&D and initial capex, such as prototype production facilities or risk-sharing regarding key aircraft technologies. For instance, in August 2024, the Federal Aviation Administration (FAA) announced that nearly USD 300 million from the Inflation Reduction Act will be used for projects that will help achieve the goal of net zero CO_2 emissions from aviation by 2050. The funds will be made available through the Fueling Aviation's Sustainable Transition (FAST),[28] which is a discretionary grant program. FAST grant awardees include established and startup fuel producers; fuel logistics and supply chain companies; engine, aircraft, and component manufacturers; state and local governments; airport authorities; and universities.[29]

- **Loans and credit enhancements**, including direct loans, loan guarantees, export agency loans, and credit insurance. All these can greatly improve access to capital and this at a much more reasonable cost where the risks involved would otherwise frequently deny access to capital or provide it at a prohibitive cost.

- **Technology insurance**, can play a role in managing risks, securing investments, ensuring operational continuity, and encouraging innovation. It can help cover technical, financial, and regulatory risks, and make SAF projects more attractive to investors and capital providers alike. However, such insurance can be hard to come by given the bespoke nature of new energy projects, and it will tend to come at a price that few such projects can afford.

Box 5: Global subsidies in favor of fossil fuels, 2022

The total amount of fossil fuel subsidies in 2022 was USD 7 trillion, equal to 7.1% of world GDP and to USD 13 million per minute.[30] The IMF calculates that ending fossil fuel subsidies would cut emissions by 34% by 2030 from 2019 levels.

Around 85% of fossil fuel subsidies are aimed at consumers as a form of welfare program that artificially keeps the price of fuel low.[31] While such programs tend to target the poor insufficiently, as fuel consumption increases disproportionately with household income, they are not the most directly distortive with respect to energy markets. Instead, it is the remaining 15% or so of total fossil fuel subsidies that are aimed directly at the companies in the oil and gas sector that can be described as harmful.

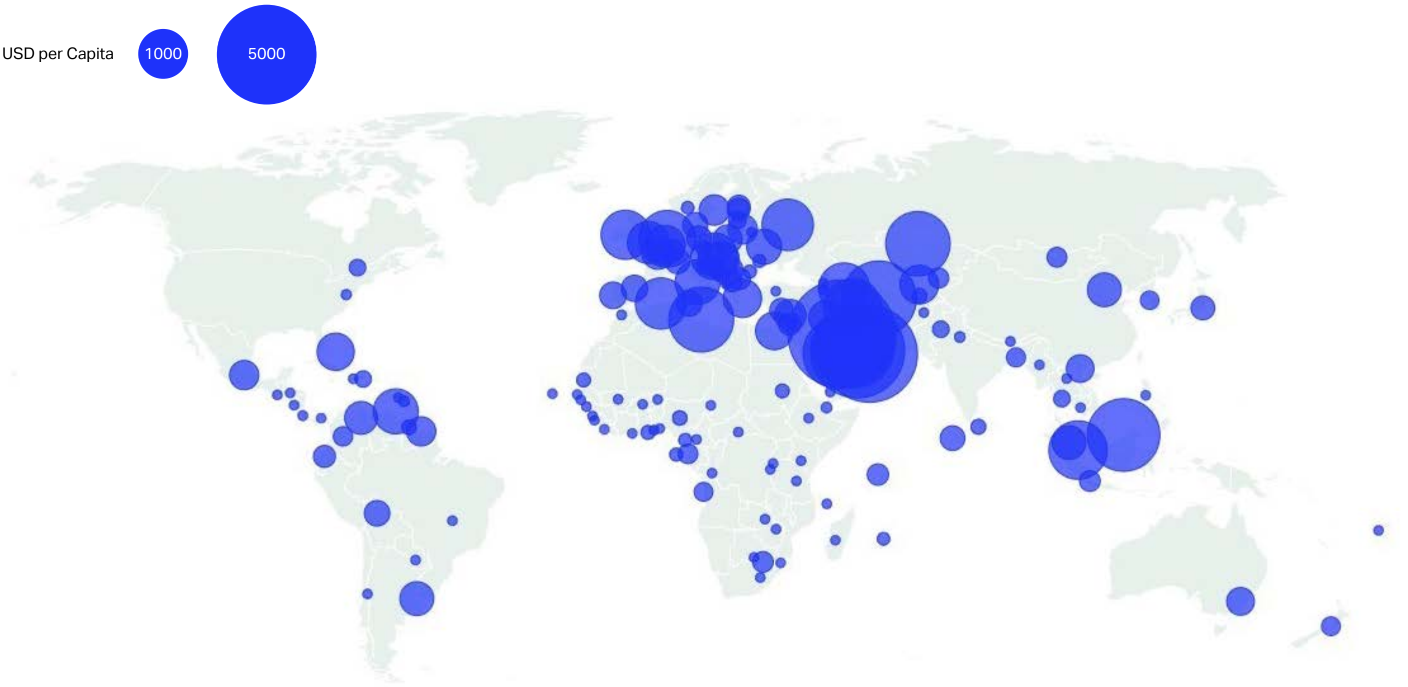
In 2022, public financial support in favor of the fossil fuel industry, in the form of subsidies, investments by state-owned enterprises, and lending from public financial institutions, exceeded a record USD 1.7 trillion globally.[32] The G20 economies committed to phasing out subsidies over the "medium-term" in 2009. All UN members followed in 2015 under the Sustainable Development Goals (SDG Target 12.c). The first global stocktaking under the Paris Agreement in 2023 called on making progress on phasing out inefficient fossil fuel subsidies "as soon as possible." Some countries have committed to reforming their fossil fuel subsidies in their nationally determined contributions (NDCs) without specifying a timeline. The G7 is the only Intergovernmental forum that has set an explicit deadline for eliminating inefficient fossil fuel subsidies in 2025, and there is, unfortunately, scant hope that this promise will be met.

Just how widespread the habit of subsidizing fossil fuels can be seen on the map below (Map 1).

Russia dominated the spending on fuel subsidies in the world in absolute terms in 2022, followed by Iran and China, according to the International Energy Agency. The US provides both direct subsidies to corporations as well as other tax benefits to the fossil fuel industry. For instance, USD 121 million was spent by the federal government on R&D funding for natural gas and petroleum liquids in 2022, and as much as USD 280 million on coal R&D. Conservative estimates put US direct subsidies to the fossil fuel industry at roughly USD 20 billion per year in 2019, with 20% currently allocated to coal and 80% to natural gas and crude oil 34. In Europe, three countries accounted for 60% of all such spending on subsidies in 2022 (European Environment Agency): France at EUR 30 billion, Italy at EUR 25 billion, and Germany at EUR 21 billion.

25 Capex refers to major, upfront investments required for new technologies and infrastructure, such as SAF plants or new hydrogen infrastructure.
26 Opex covers the ongoing costs of operating and maintaining these new systems and technologies.
27 SAF feedstock costs pertain to the expenses associated with procuring the raw materials needed to produce sustainable fuels.
28 Faa.gov (2022). Fueling Aviation's Sustainable Transition (FAST) Grants | Federal Aviation Administration.
29 Faa.gov (2024). Biden-Harris Administration Announces Nearly $300 Million in Awards for Sustainable Aviation Fuels and Technologies as part of Investing in America Agenda | Federal Aviation Administration.
30 IMF (2023). IMF Fossil Fuel Subsidies Data: 2023 Update.
31 International Energy Agency (2023). Fossil Fuels Consumption Subsidies 2022 – Analysis.
32 International Institute for Sustainable Development (2023). New Coalition Formed at COP 28 to Tackle Fossil Fuel Subsidy Reform a Promising Sign.

Map 1: Global estimates of subsidies in favor of fossil fuels (2022)



Source: OECD, IEA, IMF, UN, World Bank.[33] Disclaimer: Any data and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city, or area. Global dataset across 192 economies available until 2022.

Objective #4: Guarantee robust environmental and sustainable credentials of offsetting credits and alternative aviation fuels

Offsetting allows an organization, State, or individual to compensate for its CO_2 emissions by financing a reduction in emissions elsewhere. Carbon offsetting provides an environmentally effective option to contribute to the global reduction in CO_2 emissions while the potential for "in-house" emissions reductions is limited. This is of course the case for air transportation.

ICAO developed CORSIA, the framework for using market-based environmental policy instruments to offset CO_2 emissions in international aviation, as early as 2016. Under this framework, aircraft operators are obliged to purchase carbon credits from the carbon market. To ensure the environmental integrity of the offsetting credits for CORSIA, ICAO has established clearly defined criteria for its eligible emissions units (EEUs). Defining and adhering to such criteria is critical to ensure that the emissions reductions attained are real, accurate, and permanent.

Box 6: Guyana ART[35] Tree credits: Offsetting credits with solid environmental integrity

Guyana became the first country in the world to issue 7.14 million correspondingly adjusted carbon offsets in February 2024. The carbon offsets, with the vintage year of 2021, are generated from the Architecture for REDD+ Transactions (ART) program, one of two programs that are eligible to provide CORSIA Eligible Emission Units (EEUs) under CORSIA's first phase, from 2024 to 2026.

Guyana's jurisdictional REDD+ credits are of robust environmental integrity.[36] Jurisdictional REDD+ has the advantage of reducing the risk of inflated baselines, over-crediting, and carbon leakage. Also, to prevent double claiming, Guyana's government has integrated the corresponding adjustment[37] requirements throughout the entire process of issuing the ART Tree credits, in accordance with Article 6 of the Paris Agreement.[38] The action ensures airlines that the carbon offsets they canceled will not be double claimed by Guyana.

33 Fossil Fuel Subsidies (2022). Fossil Fuel Subsidy Tracker.
34 Coleman, C. and Dietz, E. (2019). Fact Sheet: Fossil Fuel Subsidies: A Closer Look at Tax Breaks and Societal Costs | White Papers | EESI.
35 Architecture for REDD+ Transaction (ART) is one of the programmes approved by ICAO to generate CORSIA EEUs for its first phase (2024-2026).
36 Jurisdictional REDD+ credits are generated from the activities that prevent deforestation and forest degradation of jurisdictional scale.
37 The corresponding adjustment is the action taken by the host countries to deduct the "internationally transferred mitigation outcomes" (ITMOs) use for "other international mitigation purposes", including CORSIA.
38 Art 6 Paris Agreement specifies how to conduct corresponding adjustments and the infrastructures that are needed in place.

Sustainability criteria have been adopted to strengthen the credentials of SAF, covering a comprehensive range of environmental themes.[39] Two representative sets of sustainability criteria are the CORSIA sustainability criteria for CORSIA eligible fuels and the criteria defined in the EU Renewable Energy Directive (RED).

The main differences between these two sets of criteria are:

- **Different baselines for fossil jet fuel carbon intensity:** CORSIA and EU RED have different baselines for fossil jet fuel: 89gCO_2e/MJ for CORSIA and 94gCO_2e/MJ for EU RED.[40]
- **Different minimum levels of SAF CO_2 emissions reductions:** CORSIA requires 10% net CO_2 reductions, while EU REDIII requires a minimum reduction of 65% in the life cycle CO_2 emissions.
- **Different feedstock eligibility:** Both EU RED and ICAO CORSIA consider a range of different feedstocks, and **under CORSIA**, a range of purpose grown food and feed crops (such as rapeseed and corn), as well as non-food and feed crops (such as camelina and jatropha), are eligible. New crop feedstocks can be put forward for ICAO to consider. ICAO also maintains a positive list for feedstocks considered as waste, residues, or by-products.[41] **Under EU RED**, crop feedstocks are generally eligible only if they meet the other sustainability criteria on top of the CO_2 reductions criteria. However, unhelpfully, these are not considered eligible feedstocks **under the ReFuelEU Aviation Regulation**. ReFuelEU focuses on waste and residue feedstocks listed in the EU RED's Annex IX. Recently, the EU introduced amendments to the pool of eligible feedstocks by also including, *inter alia*, intermediate crops, if cultivated under certain conditions. In addition, the EU focuses on e-SAF (commonly also referred to as Renewable fuels of non-biological origin or RFNBO in EU regulation), which uses renewable electricity and a variety of carbon sources as feedstocks.

Immediate policy actions could include:

- **Harmonization of sustainability criteria with regional and international standards:** Such alignment will help strengthen environmental integrity globally and enhance the credibility of the claims of environmental benefits made by stakeholders along the supply chain or by end users (Box 7).
- **Harmonization of technical and sustainability certification:** The global harmonization of technical and sustainability certifications can help accelerate air transport industry's decarbonization. Today, all levers required to bring aviation to net zero CO_2 emissions are subject to multiple certification processes with widely disparate specifications. Implementing measures to expedite such processes would help reduce uncertainty, cost, and time barriers to deploying SAF and other decarbonization technologies. International standards help reduce unnecessary duplication and administrative burdens (Box 7).
- **Recognition of carbon intensity of cleaner energies for aviation:** The life-cycle emissions reductions of SAF should be recognized in technology-push policies. For example, tax incentive rates and compliance values should vary in function of the specific emissions reduction potential of that type of SAF, and SAF with lower carbon intensity should benefit from higher incentives and values.
- **Develop sustainability criteria for future alternative aviation fuels:** While sustainability criteria exist for certain SAF pathways, they do not exist for aviation energy carriers such as batteries or hydrogen. It remains to be defined what the boundaries should be for life cycle emission assessment, what the relevant CO_2 reduction threshold should be (if different from what has been agreed for SAF), and what other criteria that should be considered. Accelerating air transportation's decarbonization requires that authorities anticipate developments and prepare for the arrival of new technologies.

Box 7: Facilitate dual conformance in SAF sustainability certification

In most, if not all, cases, SAF certified under the EU RED framework would also fulfill the CORSIA requirements. However, a single batch of SAF being compliant with two different schemes (such as EU RED and CORSIA) is neither explicitly excluded nor explicitly considered in the existing regulations and under existing certification rules, as the two frameworks do not currently recognize each other. As a result, SAF producers and suppliers need to predetermine which certification to opt for based on the different requirements of the airlines.[42] It would be most beneficial to the development of a global SAF market if certification under one framework could be recognized by the other and any future schemes - a process referred to as dual conformance.

Should dual conformance be implemented in the future, an economic operator certified under the CORSIA and EU RED schemes would then be in the position to issue a Proof of Sustainability (PoS) for a batch of SAF that indicates compliance with both schemes, provided that the SAF meets the sustainability requirements of CORSIA and EU RED along the full supply chain. In any case, the aircraft operator will only be able to claim the environmental attributes of the SAF purchased under one scheme, for instance, the EU ETS or CORSIA. Dual conformance would also have the added benefit of reducing costs by eliminating the need for multiple certification processes and by providing greater flexibility for the SAF producers and their buyers.

39 ICAO (November 2022). CORSIA Eligible Fuels.
40 European Union Renewable Energy Direction (EU RED).
41 This list includes wastes (such as used cooking oil and municipal 17 Understanding SAF Sustainability Certification solid waste), agricultural residues (such as cobs and manure), forestry residues (such as branches and treetops), processing residues (such as palm oil mill effluent and sewage sludge), and by-products (such as tallow and technical corn oil).
42 IATA (2024). Understanding SAF Sustainability Certification. Guidance document on requirements and criteria for sustainability certification.

Objective #5: Build SAF accounting framework with a robust chain of custody

Aircraft operators' obligations under CORSIA can also be met through SAF purchases upon presentation of purchase and blending records. Governments must enable compliance with these obligations and adopt a mechanism that allows SAF to be deployed in an environmentally and cost-efficient manner.

Immediate policy action could include:

- **Support the establishment of a fit-for-purpose global SAF accounting framework:** Such a system is necessary for all airlines to be able to meet their obligations and claim the environmental benefits associated with any SAF purchased. It will encourage SAF production and use, safeguard against double counting of environmental benefits, and stimulate voluntary commitments. Irrespective of specific policy options, a SAF accounting framework is essential administrative infrastructure if a global SAF market is to emerge (Box 8).

- **Harmonize and accelerate the standardization of all relevant certification and documentation:** All documentation with respect to the SAF batch bought by an airline, notably its environmental attributes, should be harmonized and standardized so that immutable tracking and accounting can be performed.

Box 8: A SAF accounting system with a robust chain of custody

A robust SAF accounting system—or network of interoperable systems—offers the following benefits:

- Ensures immutable tracking of the environmental attributes to enable verification.
- Provides full transparency of the claims made pertaining to any specific batch of SAF.
- Prevents double counting from double issuance, usage, or claiming.
- Allows the appropriate stacking of incentives to maximize opportunities to fund SAF purchases.

The utilization of flexible and trusted chain-of-custody mechanisms such as mass balance or book-and-claim unlocks additional benefits for increased efficiency in SAF production and transport:

- Promotes a global SAF market in which all potential producers can sell SAF to all airlines globally.
- Enables SAF production to be located where it is most cost and environmentally efficient.
- Provides increased demand for production facilities geographically distant from larger airports.
- Avoids unnecessary transport of SAF and feedstocks, minimizing the associated cost and incremental emissions while enabling more efficient deployment.
- Promotes competition by providing equal access to a global SAF market to both suppliers and customers.

Objective #6: Promote global, liquid, and transparent SAF markets

One of the major barriers to the widespread adoption of aviation cleaner energies is the high cost compared to conventional jet fuel. It is mainly through the expansion of supply and the associated economies of scale and technology learning that we expect to see that price premium shrink, making SAF and renewable energies more cost competitive. In this process, attention needs to be paid to how the energy market operates practically, and to promote its development into a global, liquid, and transparent market where competition is healthy and where new entrants and innovation can flourish.

There is a particular need to provide assistance to countries outside of the US and Europe, the two current dominant geographies in terms of SAF production, to participate in this growing market. This is necessary not only to prevent those two markets from developing oligopolistic behaviors, but also because there will not be enough SAF production to satisfy global demand if production is limited to these countries.

New markets are by definition illiquid and lacking in price transparency. Policy efforts are required to mitigate the potential market distortions and failures this can produce, and to promote liquidity and price transparency—the hallmarks of mature markets—at every junction.

In the opaque and illiquid early stages of new market creation, there is need to discourage the abuse of dominant market positions and to take steps to ensure healthy competition and the emergence of a level playing field. This can lead to more competitive pricing, better alignment between cost and value in the market, and will ultimately promote the superior product choices, thereby achieving more efficient allocation of capital. Vigilance is required with respect to price anomalies that can emerge also as a result of potentially undue secondary trading. While addressing anti-trust concerns and the need to prevent any kind of cartel-like behavior, transparency is of course an enabler in and of itself. It promotes more informed decision-making, encourages fair pricing, and fosters collaboration. It also builds trust and credibility where asymmetric information exerts a brake on investments as it complicates analysis and risk assessment.

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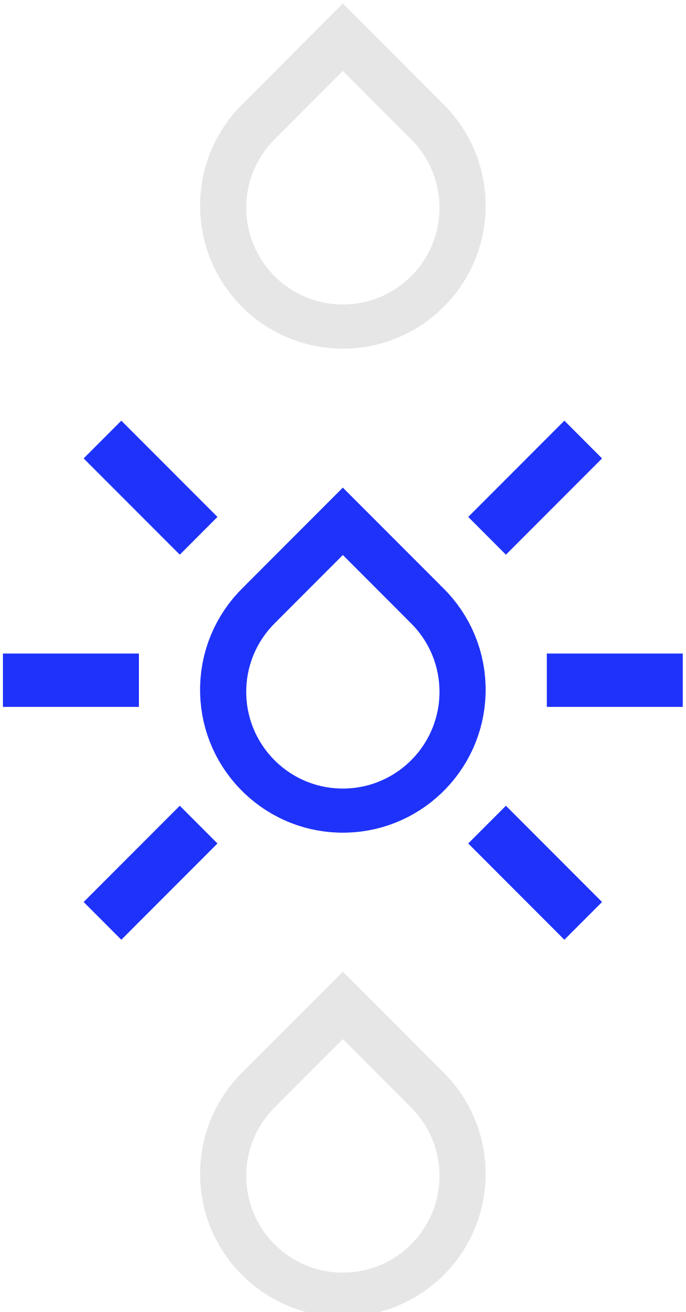
Policy making too is hampered by the associated lack of visibility. Governments and regulators need accurate trend assessments to design effective subsidies, tax incentives, and other support mechanisms. Transparency is necessary to create frameworks that address the financial needs of energy producers appropriately, without over- or under-subsidizing the market. Transparency also helps ensure that subsidies and incentives are directed to areas where they can have the most impact, such as scaling up production or reducing the cost of raw materials.

Immediate policy action could include:

- **Adopt market regulation** that promotes **competition** and ensures **fair and open** markets in SAF.
- **Assist lower-income countries** with market infrastructure developments and knowledge-sharing.
- **Promote transparency and open-source** resources wherever possible.



3.2 Mid-term policy objectives: 2026-2030

The formulation of medium-term policy actions over the 2026-2030 period is crucial for reaching 2030 targets, but also vitally important for achieving the industry's goals expressed on the 2050 horizon.

Objective #1: Eliminate barriers to distribution and end use of SAF

The challenge of increasing SAF production cannot be met unless its distribution and end use can be assured. Potential SAF producers need to know that their product can be delivered to aircraft at airports. To deliver fuel to an airport, the fuel supplier must be able to access the airport's fuel infrastructure. This infrastructure is referred to as fuel farms, and it encompasses storage and distribution facilities. Access to fuel farms' facilities depends on how their ownership is organized. Fuel farms can be owned by a single company or by a restricted group of stakeholders. Welcoming new (SAF) suppliers into their facilities might not be in the owner's interest, or it could come at a cost that would add to the already elevated price of SAF. Of course, it is also the case that limiting access not only imperils distribution but also restricts competition, lifting the cost of distribution of traditional fossil-based jet fuel as well.

IATA surveyed the ownership structure of the fuel infrastructure at 123 of the largest airports in different parts of the world, covering 48% of global fuel uplift.[43] Of these, 59% present some form of restricted access to the infrastructure due to ownership by a single fuel supplier or by a limited group of fuel suppliers, with the remaining 41% of airports providing open access.

Not all ownership structures need to be the same, and there is every reason to adapt to local specificities. Nevertheless, variations in ownership structures cannot be allowed to imperil air transportation's energy transition, and solutions need to be provided to mitigate any local restrictions on SAF distribution. Moreover, potential SAF producers need to know that their product can be delivered to aircraft at airports, and any lack of certainty on that score will impede SAF production.

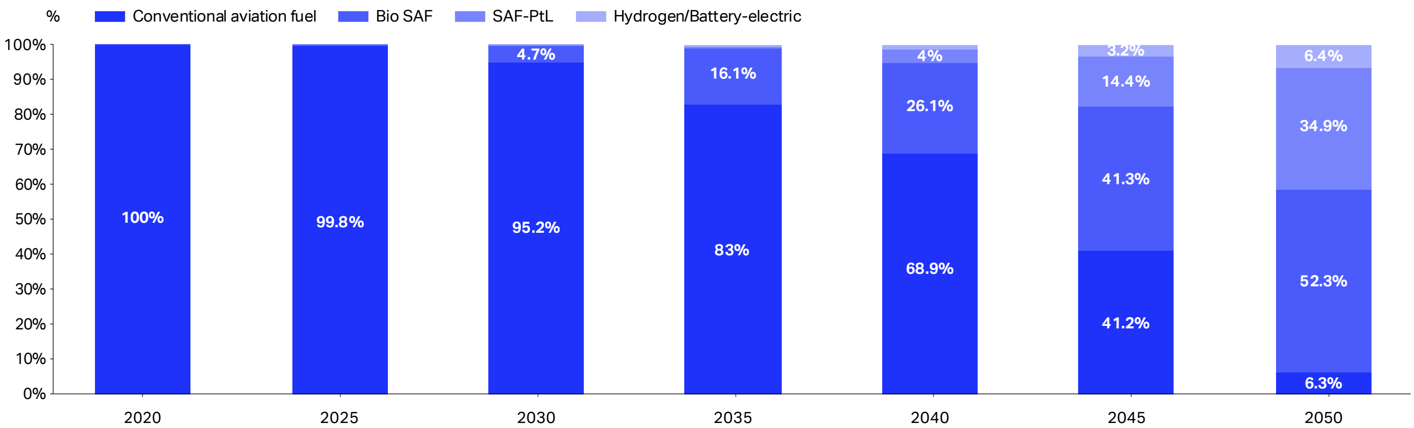
Policy actions could include:

- **Promote** open access to fuel infrastructure for SAF producers and fuel suppliers to ensure their distribution and to support open markets and free competition.
- **Mitigate and discourage** ownership structures that limit the delivery of SAF to aircraft and that award monopolistic or cartel-like pricing power to the owners of fuel infrastructure around airports.
- **Prioritize** transparent and open access to fuel infrastructure on and off the airport.

Objective #2: Drive diversification and scale-up of aviation cleaner energies for future needs

Air transportation's fuel demand cannot be satisfied by any single pathway for SAF production, nor by any single type of feedstock. It is imperative that multiple feedstocks and pathways are developed. It is likely that the maximum scaling up of bio-feedstocks will be reached by 2040, capping the total feasible production volume of SAF pathways that rely on these. Beyond 2040, alternative SAF production pathways and new propulsion technologies that use other types of feedstocks will need to have matured to satisfy the subsequent growth in demand (Chart 2).

Chart 2: Share of in-flight energy demand by energy sources under the IATA Roadmap, %



Source: IATA Sustainability and Economics

43 IATA (2024). Access to fuel infrastructure – Brief.

The main avenues to achieve aviation cleaner energies diversification are:

- Scale already approved SAF pathways, such as Alcohol-to-Jet (AtJ) and Fischer-Tropsch (FT).
- Accelerate R&D regarding SAF production pathways that are currently in development.
- Accelerated R&D for hydrogen aircraft and the infrastructure to service them.
- Scale up feedstock production and feedstock conversion technology.

The table below lists the technology pathways to produce SAF approved by ASTM[44] and blending limitations based on these pathways.[45]

Table1: SAF blending ratios and coprocessing limits

ASTM reference	Conversion process	Abbreviation	Possible feedstocks	Maximum blend ratio
ASTM D7566 Annex A1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT	Coal, natural gas, biomass	50%
ASTM D7566 Annex A2	Synthesized paraffinic kerosene from hydroprocessed esters and fatty acid	HEFA	Vegetable oils, animal fats, used cooking oils (UCO)	50%
ASTM D7566 Annex A3	Synthesized iso-paraffins from hydroprocessed fermented sugars	SIP	Biomass used for sugar production	10%
ASTM D7566 Annex A4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	FT-SKA	Coal, natural gas, biomass	50%
ASTM D7566 Annex A5	Alcohol to jet synthetic paraffinic kerosene	AtJ-SPK	Ethanol, isobutanol, and isobutene from biomass	50%
ASTM D7566 Annex A6	Catalytic hydrothermolysis jet fuel	CHJ	Vegetable oils, animal fats, used cooking oils	50%
ASTM D7566 Annex A7	Synthesized paraffinic kerosene from hydrocarbon - hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%
ASTM D7566 Annex A8	Synthetic paraffinic kerosene with aromatics	AtJ-SKA	C2-C5 alcohols from biomass	-

ASTM reference	Co-processing	Possible feedstocks	Input limit	Output limit
ASTM D1655 Annex A1	Co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery	Vegetable oils, animal fats, used cooking oils from biomass processed with petroleum	5%	-
ASTM D1655 Annex A1	Co-hydroprocessing Fischer-Tropsch hydrocarbons in a conventional petroleum refinery	Fischer-Tropsch hydrocarbons processed with petroleum	5%	-
ASTM D1655 Annex A1	Co-processing of HEFA	Hydroprocessed esters/fatty acids from biomass	24%	10%

Source: IATA SAF Handbook, May 2024

44 ASTM International, formerly known as American Society for Testing and Materials, is a standards organization that develops and publishes voluntary consensus technical international standards for a wide range of materials, products, systems, and services. Some 12,575 apply globally.

45 ASTM D7566 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons dictates fuel quality standards for non-petroleum-based jet fuel and outlines approved SAF-based fuels and the percent allowable in a blend with Jet A. ASTM D1655 Standard Specification for Aviation Turbine Fuels allows co-processing of biomass feedstocks at a petroleum refinery in blends up to 5%.

Policy actions could include:

- **State-funded R&D programs:** Public sector financial support for research and development of new feedstocks and technologies is a key enabler in air transportation's decarbonization. Such programs promote innovation through collaboration among academia, industry, and government, aligning SAF and alternative propulsion development with policy goals. For example, the Clean Aviation Program in the EU will invest EUR 380 million in clean aviation technology projects, including EUR 86 million for hydrogen aircraft and EUR 33 million for hybrid-electric aircraft.[46] The UK has committed an extra GBP 100 million of funding for cutting-edge aerospace research and development projects, mainly on zero-CO_2 technologies.[47]

- **Public-private R&D partnerships:** Through cross-sector partnerships, stakeholders can mutualize risks and share rewards, making it feasible to invest in and develop a broader range of sustainable aviation fuels, feedstocks, and new technologies. Such joint efforts can accelerate research and development, streamline commercialization processes, and enhance the scalability of diverse SAF solutions.

- **Ensuring free access to public R&D facilities**, as it democratizes the innovation process and accelerates technological advancements. Public institutions can enable a wider range of researchers and companies, including smaller firms and startups, by providing open access to state-of-the-art laboratories, testing facilities, and analytical tools to develop new technologies at lower costs. Such inclusive and "open source" and "radically collaborative" approaches to R&D have contributed to phenomenal success stories, including the accelerated development of the covid-19 vaccine and the launch and deployment of the James Webb Space Telescope. The transparency and knowledge sharing that come with free access to public R&D facilities ensures that advancements benefit the broader community and those in developing economies.

- **Grants** are instrumental in advancing the diversification and scale-up of sustainable aviation fuels and new technologies by providing essential funding at early stages of development. Grants alleviate the immediate pressure of generating financial returns and foster creativity and risk-taking in novel areas where traditional finance is reluctant to participate. As such, grants can help bridge the gap between early-stage research and commercial viability, allowing for the testing and refinement of new technologies from laboratory successes to real-world applications. Public sector grants are often the starting shot needed for others to follow, accelerating progress, enhancing competition, and ultimately driving down costs, which is necessary for widespread adoption.

Objective #3: Enhance R&D pertaining to novel carbon dioxide removal technologies

There are three actions the sector must take to get to net zero CO_2 emissions by 2050: use less fuel, change the fuel (to zero-carbon and carbon-neutral alternatives), and re-capture the residual CO_2 emissions. New technologies take time to develop and are, of course, research-intensive. Any policy initiatives that can intensify and accelerate the R&D processes will result in decarbonization solutions being brought to market more quickly. Additional research efforts are required across all potential solutions, and policies should be neutral across technologies. Picking early winners is not the name of the game when it is understood that the industry will need every lever and a multitude of technologies to achieve its decarbonization objectives.

Carbon dioxide removals (CDR) technologies will have to play a critical role in air transportation's decarbonization over the medium term for any residual emissions.[48] The International Panel on Climate Change (IPCC) defines three principles for effective carbon removal technologies:

- **Principle 1:** CO_2 must be captured and stored directly from the atmosphere and not from fossil sources.

- **Principle 2:** Durable storage of CO_2 after it has been extracted from the atmosphere must be ensured, either in reservoirs such as vegetation, soils, geological formations, the ocean, or in manufactured products. The CO_2 captured and stored may not be reintroduced into the atmosphere.

- **Principle 3:** CDR concerns the removal and storage of CO_2, which occurs through human intervention, and does not consider removal of CO_2 via natural means such as natural forestry regrowth.

CDR methods with technological maturity that can be deployed at scale today are afforestation, reforestation, and soil carbon sequestration. These can be classified as conventional CDR solutions. All other solutions fall under the novel CDR category, which refers to CDR methods and technologies that have not reached maturity or have reached maturity but are not ready for mass commercial deployment today.[49] Novel CDR technologies will need the most support from various policy instruments to support R&D, pilot testing, demonstration, and commercial scale-up. Novel CDR technologies can be divided into pre-mature technologies and mature technologies.[50]

46 Clean-aviation.eu (2023). €380 million for 8 new daring Clean Aviation projects to pave the way for highly efficient aircraft.
47 Gov.uk (2024). Business and Trade Secretary gives lift-off to over £100 million for greener air travel.
48 Policy already in place that advance the development of carbon removal technologies, such as CDR and CCUS-with the aim of promoting any prototype technology closer to the commercialization stages include the U.S. Inflation Reduction Act (s45Q) and the European Union Certification Frameworks on carbon removals.
49 The State of Carbon Dioxide Removal (n.d.). The State of Carbon Dioxide Removal.
50 Rocky Mountain Institute Applied Innovation Roadmap (2023).

1. Pre-mature technologies

Pre-mature technologies, such as certain Direct Air Capture (DAC) technologies utilizing electrochemical separation of CO_2 from ambient air or certain ocean-based CDR technologies such as Direct Ocean Capture (DOC), will need support for the related R&D activities and pre-demonstration activities, such as pilot-scale deployment. These technologies are typically considered as high-risk on investment and few private investors are prepared to shoulder such risk unassisted. Public sector will be necessary to advance these technologies.

Pre-technologically immature technologies, such as certain Direct Air Capture (DAC) technologies, will need support for the related R&D activities and scale-up.

Policy actions could include:

- **Support R&D projects (through State-funded programs and Public-private partnerships).** For instance, in 2022, the US Department of Energy (DOE) announced USD 14.5 million worth of funding to scale up direct air capture (DAC) technologies and to develop low-carbon energies, justified by the fact that DAC is not yet an economically viable technology and requires consistent investment to become established. On the other side of the Atlantic, the European Commission has also supported DAC through various research and innovation programs, including Horizon Europe.[51]

- **Grants**, targeted towards R&D and pilot-scale deployment. For instance, Australia recently awarded an AUD 65 million grant to seven promising carbon capture projects. The grant aims to develop new CO_2 capture technologies to reduce emissions from hard-to-abate industries, moving Australia towards a net zero CO_2 footprint.[52] The US government also recently announced USD 14 million in funding for R&D towards marine CDR strategies.[53] The UK similarly provided over GBP 54 million in grants for projects developing new CDR technologies in 2021.[54]

2. Mature technologies

Mature technologies are technologies that have reached technical viability, but are not quite ready for large-scale commercial deployment, such as Bioenergy with Carbon Capture and Storage (BECCS) or biochar. As technologies mature and become ready for commercial deployment, they will require much more financial support to develop commercial-scale projects and ensure that there will be appropriate demand for CDR credits generated by these projects when they come online. Policy actions should, therefore, focus on supporting demonstration activities and project development through public funding and encouraging more private investments.

Policy actions could include:

- **Public procurement** in commercial-scale projects can provide projects with new and more stable revenue and thereby help catalyze the CDR market. For instance, in September 2023, the US Department of Energy's Office of Fossil Energy and Carbon Management (FECM) announced up to USD 35 million in cash awards through offtake agreements to commercial-scale CDR activities. Phase 1 awards for this program were announced in May 2024. Through federal purchases of CDR, the program mainly aims to direct the DOE to procure an increasing amount of four different novel CDR pathways, including DAC and BECCS, culminating in the removal of 10 million net tonnes of carbon dioxide on a lifecycle basis starting in fiscal year 2035.[55]

- **Tax credits** allow projects to be eligible for performance-based tax reductions and immediately cut costs and curtail the risk of investing in CDR technologies. For example, the 45Q tax credit under US Inflation Reduction Act, awards up to USD 180 per tonne of CO_2 removed from DAC projects that has the capacity to remove at least 1,000 tonnes of CO_2 from the atmosphere per year.[56]

- **Loans and credit enhancements**, including direct loans, loans at preferential rates, loan guarantees, export agency loans, and credit insurance, can both make capital available and lower its cost, thereby reducing the risk for investors and, making it more attractive for the private sector to get involved in CDR initiatives.

- **Grants** towards developing commercial-scale projects. For example, the Regional Direct Air Capture (DAC) Hubs program by the US Department of Energy funded USD 3.5 billion towards four domestic DAC projects with the potential to capture at least 1 million tonnes of CO_2 from the atmosphere annually. The funding provided will help to accelerate the demonstration and deployment of DAC technologies.[57] Funding programs through the EU Innovation Fund[58] also assist in the development of commercial-scale CDR projects.

51 European Commission (2021). Horizon Europe.
52 DAWE (2024). Carbon Capture Technologies Program grant recipients announced.
53 Noaa.gov (2023). Biden-Harris Administration announces $14 million as part of Investing in America agenda to support research for new ocean-based climate solutions.
54 Gov.uk (2024). Projects developing innovative carbon removal tech benefit from over £54 million government funding.
55 Energy.gov (n.d.). DOE Announces $35 Million to Accelerate Carbon Dioxide Removal.
56 Carbon Capture Coalition (2023). What is the Section 45Q Carbon Capture Tax Credit?
57 Energy.gov (n.d.). Regional Direct Air Capture Hubs.
58 European Commission (2024). What is the Innovation Fund?

3.3 Long-term policy objectives: 2031-2050

Given the lack of mature solutions for air transportation's energy transition and the long lead times for developing such mature solutions, plans must be made today to ensure their availability by 2050.

Objective #1: Conduct periodic policy reviews and assessments to guide future policies

Policy development is complex, particularly in dynamic areas such as sustainability and aviation. Best regulatory practice suggests that policymakers should establish a periodic review mechanism to assess policy effectiveness and evaluate the various design elements to ensure they remain fit for purpose over time.

Such reviews enable policymakers to pinpoint any distortions, loopholes, or unintended consequences that might impede progress toward the desired policy goal—net zero CO_2 emissions in this case. It would also allow for timely adjustments to design elements or for the revocation of ineffective policies or policies that are no longer required. Such reviews are already being used, including in CORSIA and in the UK SAF mandate.

In the longer term, maintaining policy flexibility and adaptability is vital to ensure that the policy remains relevant and abreast with any rapidly evolving technological advancements, such as the development of more fuel-efficient aircraft and alternative sustainable aviation fuels. This approach both facilitates the integration of innovative technologies and ensures that policies respond to the evolving landscape of aviation sustainability.

Policy actions could include:

- **Develop and adopt a standardized CO_2 emissions tracking and reporting methodology:** The methodology should be data-driven and foster global consistency. International alignment is essential to facilitate collaboration, enable policy harmonization, and advance collective efforts toward the industry's net zero CO_2 emissions goal.

- **Conduct policy effectiveness assessment at least every five years to ensure the enacted policies stay fit for purpose.** Assessments based on empirical data should reveal whether the intended policy objective has been achieved, identify any unintended consequences, and recommend necessary adjustments to policy design elements.

- **Incorporate exit strategies for when policies are no longer needed.** Eradicating outdated laws, rules, and regulations can bring great benefits in terms of efficiency gains and productivity in general. When it comes to market-specific regulation, designed to create, and grow new markets, it is perhaps even more necessary to retire obsolete incentives that can distort more mature markets and potentially produce perverse and even opposite effects to the original policy impulse. Of course, the most flagrant example of such incentives that are now harmful in today's global policy context are those in favor of fossil fuel producers.

Objective #2: Foster continuous innovation in non-biological SAF

For air transportation to reach net zero CO_2 emissions in 2050, about 500 Mt of SAF would have to be produced in 2050.[59] Put simply, in the 20 years between 2030 and 2050, SAF must scale up more than 36 times, assuming that the ambitious CAAF/3 collective vision for 2030 will have been achieved. Limited production capacity of biological-origin SAF (e.g., the HEFA pathway) means that SAF produced from non-biological feedstocks will be necessary for the expected demand to be met.

In this context, more targeted incentives are essential to bolster research, development, and the production of non-biological SAF.

Policy actions could include:

- The policy actions that will drive innovation, development, and commercial viability of non-biological SAF are the technology-push measures detailed above regarding all new markets and technologies that will be necessary to achieve net zero CO_2 air transportation incrementally and to bring it to steady-state sustainable aviation beyond the 2050 horizon. These shall be coupled with demand-pull measures that increase as technologies and markets mature. As such maturity lies a number of years into the future, it requires foresight and purpose to allocate funds and develop certifications at this early stage, stressing the need for the formulation of nation-wide energy strategies with a clear and long-term vision.

59 IATA (2023). Energy and New Fuels Infrastructure Net Zero Roadmap.

Objective #3: Adopt new propulsion technologies

Aircraft manufacturers and OEMs expect hydrogen-powered aircraft to enter service in the 2030s.[60] This presents an exciting opportunity to address aviation's CO_2 emissions definitively. Equally, however, it requires the implementation of several enabling policy measures.

Policy actions could include:

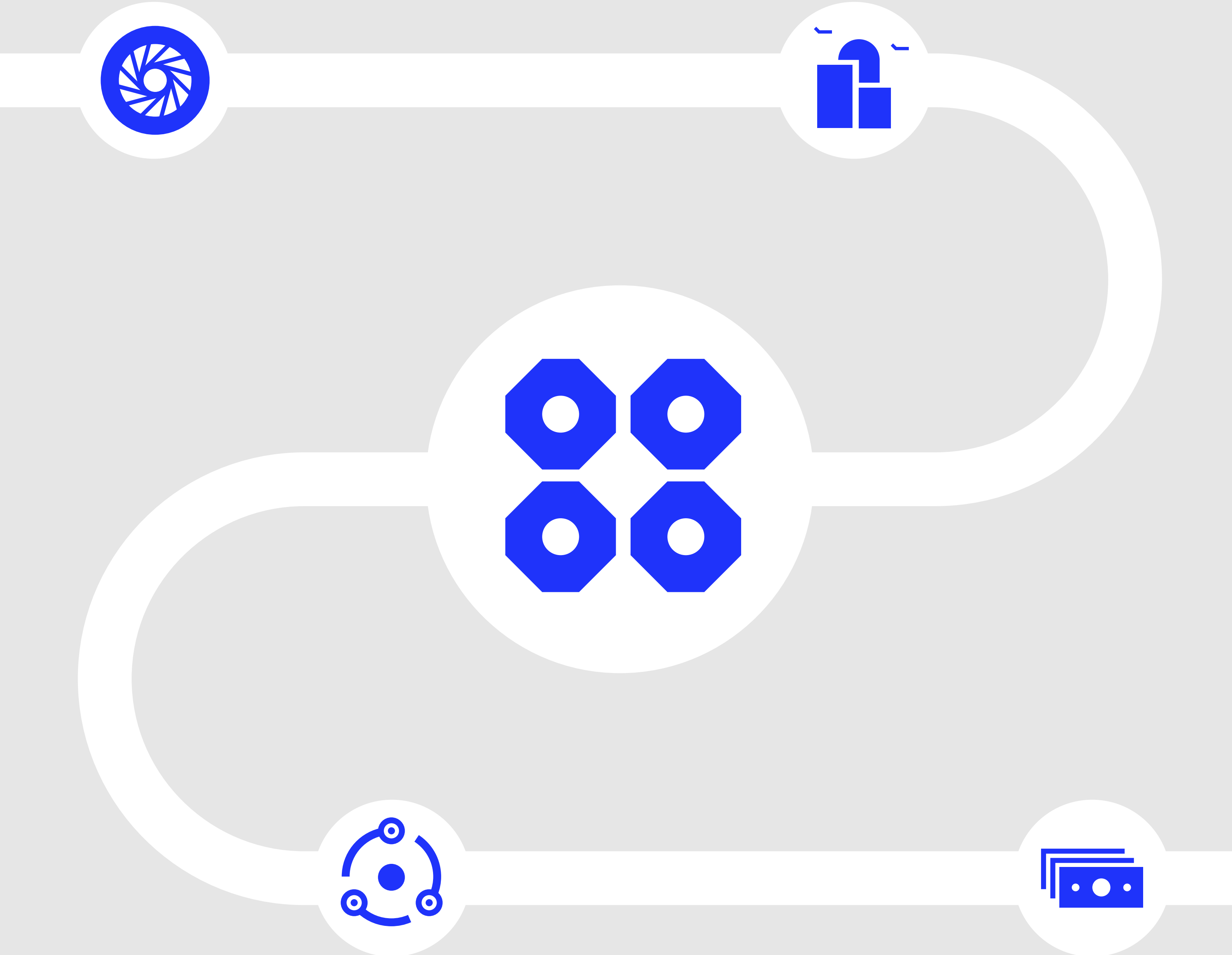
- **State investment into R&D** for revolutionary aircraft concepts, redesigns, and prototypes.[61]
- **Develop the airworthiness standards and certification process for deploying hydrogen for long-haul flights.**
- **Support R&D investment to develop solutions that can ensure safe and fast refueling (or recharging, if electric) for seamless aircraft turnaround procedures.**

Operational standards also need to be developed expeditiously.

This could include the following policy actions:

- **The continuous revision of technical fuel standards and potential supply chain issues.**
- **Global harmonization of refueling standards and recommended practices for hydrogen**, as well as sensing and safety equipment required for turnaround procedures and MRO operations.
- **Internationally accepted criteria** to evaluate and assess the life-cycle emissions benefits of hydrogen and electric aircraft.

60 IATA (2023). Aircraft Technology Net Zero Roadmap.
61 Some examples which have been highlighted in the previous section.



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