CHILE: SAF ROADMAP 2050

Sustainable Aviation Fuels

Ministerio de Energía
Gobierno de Chile

Ministerio de Transportes y Telecomunicaciones
Gobierno de Chile

Junta de Aeronáutica Civil
Ministerio de Transportes y Telecomunicaciones
Gobierno de Chile

Agencia de Sostenibilidad Energética

Vuelo limpio

IDB

Chile: SAF Roadmap 2050

Document collaboratively prepared by

Supported by

ADVISORY TEAM

- Ministry of Energy: Karla Chace and Álvaro Ruiz.
- Civil Aeronautics Board: Romina Altamirano, Sebastián Flores, and Martín Mackenna.
- Energy Sustainability Agency: Yerko Arteaga, Javiera Brañes, Fernanda Cabañas, and Fabián Olave.
- Inter-American Development Bank: Cristian Navas and Mariano Ansaldo.
- Consultants: Mauricio Utreras and Constanza Montecinos.
- *Empresa Nacional del Petróleo:* Sebastián Córdoba, Gina Gonthier, Marcelo Guerrero, and Paulina Valenzuela.

DESIGN

Margarita Valenzuela.

ACKNOWLEDGMENTS

The Ministry of Energy, the Civil Aeronautics Board of the Ministry of Transport and Telecommunications and the Energy Sustainability Agency, through the Vuelo Limpio Program (Clean Flight), thank all the people and entities that participated in the SAF Roundtable. This includes the presenters and assistants, the Advisory Committee and the technical counterparts of the Ministries of Agriculture; Science, Technology, Knowledge and Innovation; Economy, Development and Tourism; Education; Environment; Public Works; Foreign Affairs and the Directorate General of Civil Aviation.

We also thank Adriano Doniez, David Dueñas, Heinz Doebbel, Ignacio Rivas, Inmaculada Gómez, Löic Lespagnol, Marcelo Méndez and Margarita Amaya, for their contributions to this document.

Lastly, to Corinne Ribbons, Josh Knight, Randy Franks, Sam Stephens, Sebastian Eder and Will Phillips, for their input on the English translation.

Vuelo Limpio, or Clean Flight, is a national and voluntary program, managed by the Energy Sustainability Agency and the Civil Aeronautics Board, which seeks to advance the energy sustainability of aviation in Chile.

April 2024 (Spanish Edition)
August 2024 (English Edition)

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Diego Pardow

Minister of Energy

At the Ministry of Energy, we recognize the impact generated by energy uses on Greenhouse Gas (GHG) emissions. In turn, we prioritize advancing public policies in favor of their mitigation and adaptation to climate change. In this way, the *Vuelo Limpio* program, or Clean Flight, together with the Ministry of Energy, have developed important measures linked to the decarbonization of aviation in Chile through the SAF Roadmap.

In 2022 the International Civil Aviation Organization (ICAO), a specialized agency of the UN, of which our country is a Member State, agreed to the Long-Term Aspirational Goal (LTAG) that aviation will reach net zero CO_2 emissions by the year 2050. To this end, studies commissioned by ICAO have determined that Sustainable Aviation Fuels (SAF) would drive global CO_2 reductions. In light of these studies, a global framework was agreed to achieve the clean energy transition in international aviation, seeking to promote the production and use of SAF around the world. The goal is in line with what was agreed at the 28th Conference of the Parties (COP28) of the United Nations Framework Convention on Climate Change (UNFCCC), which seeks to leave behind the use of fossil fuels by 2050.

Now, with Chile's great potential in the development of renewable energies and new energy sources, there is an opportunity to promote policies that promote the production and use of SAF and thus contribute to the country's energy transition and decarbonization process. Instruments such as the National Energy Policy (*Política Energética Nacional*, PEN), the National Green Hydrogen Strategy and the Green Hydrogen Action Plan 2023-2030, together with the National Electromobility Strategy, reflect the great efforts that we have promoted in this area.

In this manner, Chile joins international initiatives in recognizing the role of SAF in the decarbonization of the aeronautical sector, highlighting the need to explore and develop this sustainable industry at the local level. Like green hydrogen and its derivatives, e-fuels or synthetic fuels constitute a great opportunity for our country, but their scaling also poses great challenges. This Roadmap proposes the first actions to mitigate these challenges and establish this new potential safely and securely.

To properly implement the SAF Roadmap, it is essential to have the active participation of all actors in the value chain. Accordingly, the collaboration of both public and private entities will facilitate the development of the proposals contained in this document.

The transition process towards a low-emission energy matrix, which makes it possible to confront the climate crisis and achieve decarbonization goals at a global level, is already underway. I am sure that this SAF Roadmap will contribute to achieving this objective.

Juan Carlos Muñoz
Minister of Transportation and Telecommunications

Since its beginnings in the 20th century, air transport has played a fundamental role in global connectivity, providing benefits in areas such as economic growth, social development, trade facilitation and tourism.

Chile's unique geography and location have made air transportation essential to connect cities efficiently, quickly and safely, both inside and outside our borders.

This essential role of connection that the sector plays and the challenges of caring for the planet posed by the world stage, make it crucial to focus efforts to make aviation a tool that allows us to achieve the Sustainable Development Goals (SDGs). For this, we must work tirelessly through balanced management of the economic, social and environmental spheres.

Our country is firmly committed to decarbonization and in this transportation faces a great challenge. This sector is responsible for 25% of GHG emissions in the national territory, which is why a series of policies and mitigation measures have been implemented in this space. These measures are closely linked to the promotion of electromobility and to the use of new energy sources such as renewable hydrogen. As a Government, we are determined to continue advancing in this direction, seeking to promote innovative and sustainable solutions to decarbonize transportation.

In the field of international air transport, there is a global commitment to achieve net zero emissions by 2050. The ICAO has proposed a basket of measures to achieve this, covering technological and operational aspects, in addition to market-based measures and SAF. The promotion of SAF represents one of the key measures because they can be applied in the short and medium term, allowing us to achieve significant emission reduction in this industry that is difficult to abate.

To advance in these areas, in Chile the Clean Flight program is playing the role of a promoter of public-private collaboration, bringing together different industry actors who highlighted the need to initiate actions to develop SAF on national soil. From this, the SAF Roundtable emerged, coordinated with the support of the Inter-American Development Bank (IDB), aiming to gather background information to prepare this roadmap. This roadmap is proposed as the starting point of a series of actions that will allow the production of this alternative fuel source.

The development of SAF represents a fundamental contribution to the sustainability of air transport. At the Ministry of Transport and Telecommunications, we are fully convinced that the SAF Roadmap outlines an adequate path to promote the decarbonization of aviation. From now on, we commit to continue to give this work the priority it deserves, and to work hand in hand with the various actors involved to make this important goal a reality.

Rosa Riquelme

Executive Director of the Energy Sustainability Agency

The Clean Flight program, *Vuelo Limpio*, began in 2020 with a clear objective: contribute to aviation in Chile moving towards energy sustainability. With a structure already defined, in 2021 *Vuelo Limpio* was established as a pilot project with a strong component of public-private collaboration, creating the roles for air operators and associated organizations. This milestone allowed the formalization of partnerships with national aircraft operators. These entities joined voluntarily and with a notable commitment to contribute to the program's objectives.

To understand the vision of those partners, during a workshop, the need to work on advancing the development of SAF in Chile was raised. The challenge was assumed by *Vuelo Limpio*. Thus, in 2022 the work that drives this Roadmap began with broad participation from industry, creating a SAF Ecosystem of more than 60 institutions by 2023, comprised of national, international and academic organizations.

The Energy Sustainability Agency, in its role as implementer of public policies in collaboration with the Ministry of Energy, has managed to generate significant impacts in areas such as electromobility and the development of green hydrogen. With the implementation of this Roadmap, our objective is to replicate this success and advance the transition towards more sustainable and environmentally friendly aviation, with Clean Flight, as the leading program in promoting the consolidation of the SAF in Chile.

Martín Mackenna

Secretary General of the Civil Aeronautics Board

At the Civil Aeronautics Board, we are convinced that decarbonization is the greatest challenge for aviation in this century. As the body that exercises senior management of aviation in Chile, we have strongly supported this process that will allow us to continue growing in offering the important benefits of air transport in a sustainable way.

To achieve this purpose, we must work in coordination with other countries to generate public policies that allow us to reach decarbonization. For this reason, we believe that the role of ICAO and regional organizations such as the Latin American Civil Aviation Commision (LACAC) is fundamental. Along with the development of our Roadmap, we have actively participated in international meetings, such as ICAO's 41st Assembly and the CAAF/3, where global goals and other objectives focused on the decarbonization of aviation were established. This involvement has allowed us to acquire knowledge and experience at an international level, as well as to share our progress, especially in the Latin American region. A notable example of this is this SAF 2050 Roadmap and our participation in the ICAO ACT-SAF program, which has allowed us to secure funding to carry out the first SAF feasibility study in Chile, funded by the Netherlands, a milestone that marks the beginning of the implementation of this Roadmap.

All of the above demonstrates our commitment to this issue and also supports the idea that Chile has opportunities to develop SAF. Thus, the work carried out globally, added to this Roadmap, constitutes a collection of actions that will grow over time, to achieve net zero emissions from aviation in Chile.

Executive summary

Facing the climate crisis and achieving global decarbonization goals requires an energy transition process that encompasses all productive sectors, however, the transport sector is key.

- In line with the 2015 Paris Agreement on Climate Change, in October 2022 the international aviation community established the Long-Term Aspirational Goal to **achieve net-zero CO_2 emissions by 2050**[1].
- During the Third Conference on Aviation and Alternative Fuels (CAAF/3) organized by the International Civil Aviation Organization (ICAO) in November 2023, a global framework was agreed upon to **achieve a clean energy transition in international aviation**. Under this framework, ICAO and its Member States have agreed to: strive to achieve a collective global aspirational Vision to reduce CO_2 emissions in international aviation by 5% by 2030 compared to a zero clean energy scenario, through the use of SAF, Lower Carbon Aviation Fuels (LCAF) and other cleaner sources of energy for aviation and to **promote the production of Sustainable Aviation Fuels (SAF) in all geographies**.

A basket of measures is available to achieve these decarbonization goals. However, SAF can generate the greatest contribution to decarbonization for three main reasons:

They can be produced from biomass, waste, captured CO_2, and hydrogen.

They are drop-in fuels, so they can be used on current aircraft with existing airport infrastructure.

They could reduce GHG emissions by up to 99% when the entire life cycle is considered[2].

[1] *Resolution A41-21, ICAO.*

[2] *When considering the pathway power-to-liquid (PtL).*

Under these agreements for the decarbonization of international aviation, Chile faces the challenge of promoting the deployment of SAF. Through the Clean Flight program, the Ministry of Transportation and Telecommunications and the Ministry of Energy, in collaboration with the Energy Sustainability Agency, and with the support of the Inter-American Development Bank (IDB), set up a public-private initiative called the **SAF Roundtable**. It aimed to gather input from the stakeholders in the fuel, aviation, and waste industries that could play a role in the future SAF value chain to develop Chile's first SAF Roadmap. This marked an important milestone as one of the first initiatives of its kind in Latin America.

The SAF Roundtable identified two main perspectives within the private sector. In the **energy sector**, comprised mainly of fuel companies, it was noted that, given the emissions reduction potential of SAF, the development of this type of fuel is aligned with the sector's energy transition objectives. In the **transportation sector**, represented by airlines, the emphasis was on the need to develop a SAF market in Chile to be able to access this type of fuel while minimizing its economic impact.

In addition, the roundtable highlighted **that there are favorable conditions for the production of SAF in Chile, due to the potential for the development of hydrogen-derived fuels from renewable sources, and the existence of raw materials, such as used cooking oils, forest biomass residues, and crops with high lipid content.** However, on the road to becoming an actor in SAF development in the region and beginning to explore this potential, Chile must overcome a series of challenges in terms of regulatory, economic, territorial, social, technological, and competitive issues, among others.

The roundtable identified 5 axes[3] with 26 associated actions to address these challenges and establish enabling conditions. The five axes are:

This structure provides the means to address the challenges identified by the SAF Roundtable and proposes a work plan for actions corresponding to each of the axes in the coming years. The aim is to use SAF to achieve Chile's global goals of carbon neutrality for the aviation industry.

[3] *The order of the axes does not indicate priority.*

Our ambition

The SAF Roadmap sets a **goal for SAF to constitute 50% of the fuel used in Chile's national and international aviation by 2050.** This goal takes into account international climate commitments and is strongly linked to other national policies, such as the Long-Term Climate Strategy (LTCS), the National Energy Policy (*Política Energética Nacional*), the National Green Hydrogen Strategy, the Green Hydrogen Action Plan 2023–2030, and other initiatives that contribute to the process of decarbonization of air transport in Chile.

This roadmap will contribute not only to the decarbonization of air transport, but will also lay the foundation for Chile to advance in energy independence, promote local and sustainable productive development, and generate a pioneering SAF industry in the region.

50%

Share of SAF used in aviation in Chile by 2050.

First Milestones

The milestones positioned as most relevant for the implementation of the SAF Roadmap are outlined as follows.

1

STUDIES

Carry out studies in the next two years on the technical and economic feasibility of the raw materials to produce SAF in Chile, in addition to the logistics associated with SAF.

2

REGULATION AND MARKET

Establish a work plan to address regulatory and policy needs to produce, distribute, and consume the different types of SAF by 2026.

3

AGREEMENTS

Promote market development and collaboration for the production of SAF in Chile through national and international agreements.

4

PRODUCTION

Produce the first liter of SAF during the next three years by promoting research and development in national facilities.

5

SAF PILOT

Build the first SAF pilot plant before 2030 to enable larger-scale production.

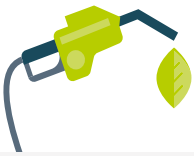
Introduction

In the context of the fight against climate change, countries have made significant commitments to achieve carbon neutrality by 2050. While the aviation sector is responsible for only 2% of global GHG emissions[4], the industry is no stranger to the climate change challenge; to put it into perspective, if aviation were a country, it would rank among the top 10 nations worldwide in terms of GHG emissions[5]. It is also crucial to acknowledge that aviation is inherently a hard-to-abate sector.

The international aviation industry has established its own goal of net-zero carbon emissions by 2050. Various institutions[1,6,7] have studied the ways to achieve this goal, reaching the same conclusion: there is no single path to decarbonizing this industry. Thus, in recent years technical organizations such as ICAO have developed recommendations based on a basket of measures consisting of the following:

TECHNOLOGICAL ADVANCES: more fuel-efficient aircrafts in addition to new technologies such as electric, hybrid and hydrogen aircraft.

OPERATIONAL AND INFRASTRUCTURE IMPROVEMENTS: optimization of air traffic management and operational procedures on the ground and in the air.



USE OF SAF: replace the use of fossil fuels with SAF, which have a lower carbon footprint.

MARKET-BASED MEASURES: such as the carbon credit mechanism. In the case of international aviation, this mechanism is governed by the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Considering the contribution of each of these measures to net zero, **SAF would have the greatest decarbonization potential for aviation**.

For this reason, and without neglecting the importance of developing the rest of the measures, the Clean Flight Program decided to **move forward with the creation of this SAF Roadmap in Chile.**

[4] *Hannah Ritchie (2020) - "Climate change and flying: what share of global CO_2 emissions come from aviation?".*

[5] *Reducing emissions from aviation, Climate Action. European Commission*

[6] *Waypoint 2050 - Aviation, ATAG, 2021.*

[7] *Aviation Sustainability Briefing - Edición 9, Eurocontrol.*

What Are Sustainable Aviation Fuels?

According to the Convention on International Civil Aviation, SAF are defined as renewable or waste-derived aeronautical fuels that meet CORSIA sustainability criteria (Annex 16 – Environmental Protection, Volume IV, CORSIA).

SAF can replace fossil fuels without requiring modifications to aircrafts, and could reduce GHG emissions by up to 99% compared to conventional fuels from a life cycle perspective.

However, it is important to mention that there are **barriers** to decarbonization through the use of SAF, in particular the fact that the availability of this fuel currently tends to be low worldwide. Thus there is a need to design public policies to overcome these barriers and develop this market along the same lines as policies already implemented by various countries to deploy renewable energies such as wind and solar[8]. In this context, the Clean Flight program, managed by the Civil Aeronautics Board (JAC, by its acronym in Spanish) of the Ministry of Transportation and Telecommunications (MTT) and the Energy Sustainability Agency (AgenciaSE, by its acronym in Spanish), together with the Ministry of Energy (MEN) and the Inter-American Development Bank (IDB), promoted the development of this SAF Roadmap. It aims to generate enabling conditions to develop these fuels in Chile and move towards the goal of net-zero CO_2 emissions in the aviation industry by 2050. The National Petroleum Company (ENAP, by its acronym in Spanish) also participated in this initiative by sharing its experiences with renewable fuels.

As part of a Public-Private SAF Roundtable, five sessions were held to prepare the SAF Roadmap (see Appendix). The aim was to determine the barriers, challenges, and opportunities for the development of this industry from the perspective of entities in the fuel and aviation sector that would participate in the SAF value chain in Chile. Through these sessions, it was concluded that most of the challenges identified derived from one main barrier: high production cost and, therefore, a high market price, which places the price of SAF between two and four times higher than traditional fuels[8,9].

The SAF Roundtable sessions also gathered background information on the absence of regulation in the area of SAF and the need for advanced human capital, among other issues. Thus, the Roadmap proposes five axes of action: **capacity building (axis 1), regulation (axis 2), market development (axis 3), SAF ecosystem (axis 4) and technology (axis 5)**.

The SAF Roadmap aims to address these axes through specific guidelines and specific tasks that involve actions by both public and private agents. The roadmap also establishes monitoring methodologies and opportunities for citizen participation for both the initial implementation of the roadmap and future updates. In this sense, the Roadmap is a starting point that also considers the review and update of this instrument every three years by the Clean Flight program with the participating ministries and agencies. The monitoring and development of this Roadmap is a major step towards compliance with the international agreements adopted by Chile before the ICAO, in line with the Paris Agreement.

[8] *Clean Skies for Tomorrow: Sustainable Aviation Fuel Policy Toolkit, World Economic Forum, 2021.*

[9] *Working Paper A41-WP/477, ICAO.*

1. The aviation industry and climate change

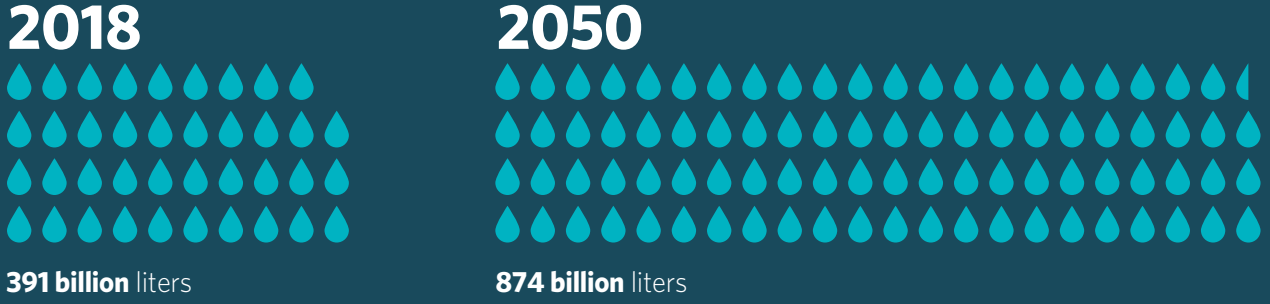
1.1. Fuel consumption and GHG emissions

In recent decades, the aviation sector has experienced significant expansion due to the rise of new routes and the demand for global connectivity. Worldwide, there has been a 5.4% average annual increase in passengers[10]. This has generated an impact not only on passenger and cargo air traffic but also on the entire value chain linked to its operations. In Chile, like other developing countries, growth rates are even higher and have the potential to remain high in the coming years.

According to projections by the U.S. Energy Information Administration (EIA), aviation fuel consumption is expected to increase at a faster rate than any other liquid fuel for the transportation sector until 2050. Where global use of commercial jet fuel is expected to more than double, from 391 billion liters in 2018 to 874 billion liters in 2050.

Currently, aviation is responsible for 2% of GHG emissions and 2.5% of CO_2 emissions[11], with an increase projected as other sectors decarbonize. According to ICAO projections[12] (prior to the COVID-19 pandemic), in a business-as-usual scenario with no action taken, CO_2 emissions from the international aviation sector are expected to triple by 2050 compared to 2015. Therefore, decarbonization will become one of the main challenges for this industry in the future.

FUEL CONSUMPTION IN 2018 AND FORECASTING THROUGH 2050



[10] *World Development Indicators (1974 - 2019). World Bank.*

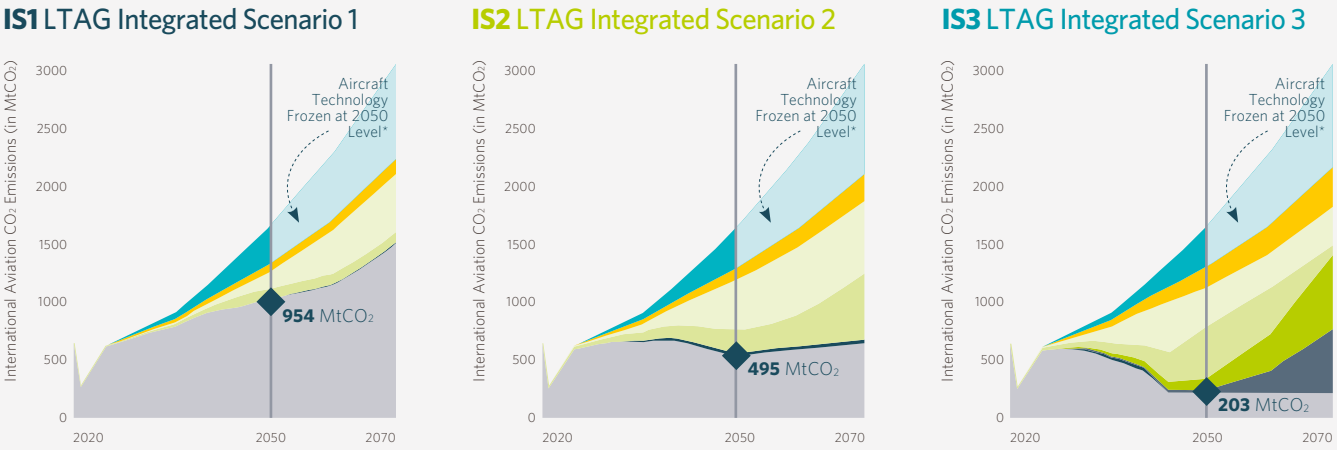
[11] *Hannah Ritchie (2020). "Climate change and flying: what share of global CO_2 emissions come from aviation?".*

[12] *Working Paper A40-WP/560, ICAO.*

1.2. The energy transition as a key piece in the decarbonization of aviation

As noted above, ICAO has proposed a basket of measures to achieve the goal of net zero carbon dioxide emissions by 2050. According to an ICAO report[13] that evaluated three integrated scenarios, achieving this goal requires that the measures associated with the use of fuels contribute between 15% (IS1) and 55% (IS3) of the CO_2 emissions reduction (Figure 1).

Figure 1. CO_2 emissions scenarios and contribution to carbon neutrality of the basket of measures proposed by the International Civil Aviation Organization. *Source: ICAO, "Long Term Global Aspirational Goal (LTAG) for International Aviation", 2022.*



* Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternative scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

[13] LTAG Report, ICAO, 2022.

2. Sustainable Aviation Fuels (SAF)

2.1. Five key ways to ensure SAF as an energy source

Below are the five key ways to ensure the sustainability of SAF as an energy source in the years ahead.

1

Replacement of fossil fuel for jets

SAF are drop-in fuels, that is, they can be used for conventional aircraft without the need to change or adapt the aircraft technology or airport infrastructure. Thus, they can be used in the short term without compromising flight safety or autonomy. Currently, SAF are mixed with conventional fuel at rates that reach up to 50%, a proportion that is expected to increase. Aircraft manufacturers project that they will be able to operate with 100% SAF by 2030[14,15].

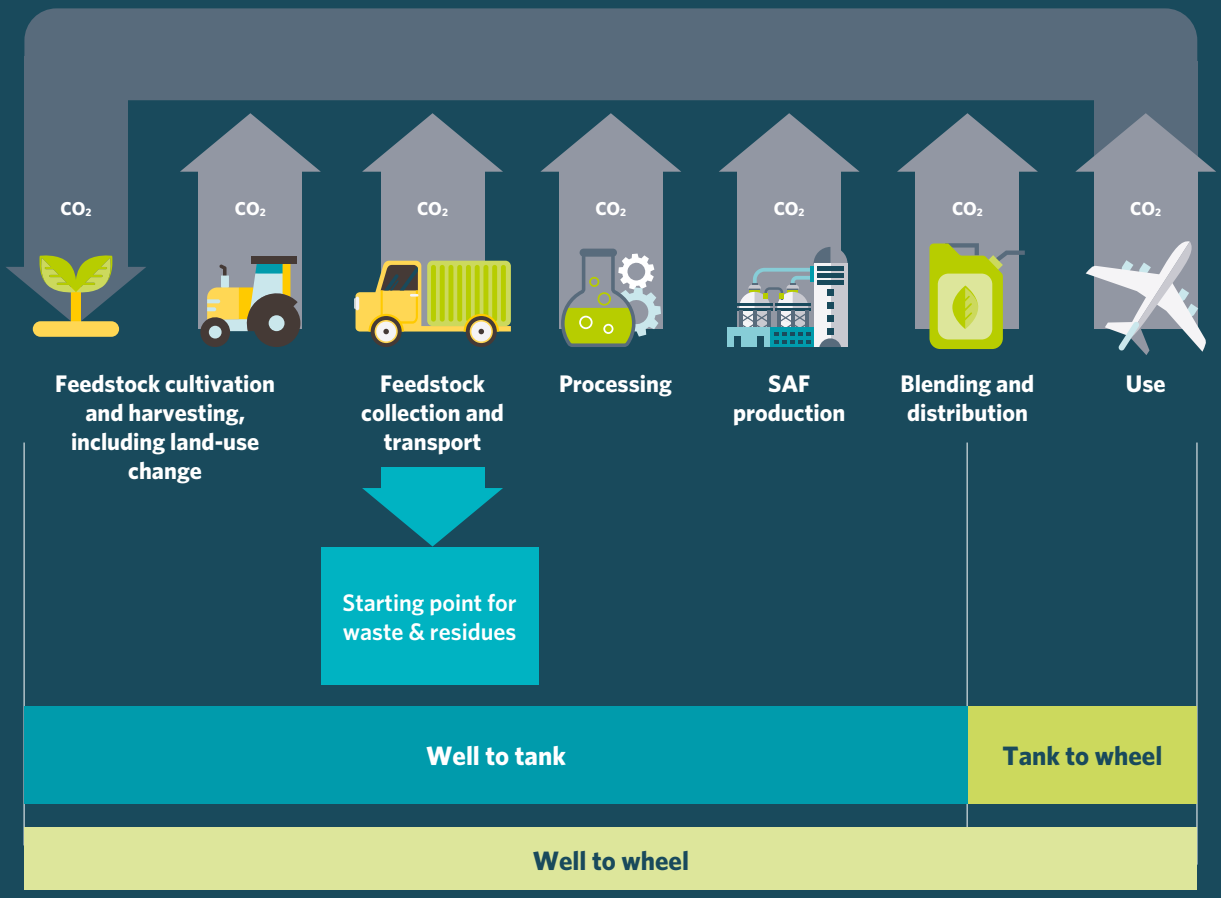
[14] *Sustainable Aviation Fuel - Fact Sheet, Boeing, abril 2023.*

[15] *Sustainable Aviation Fuel, Airbus.*

Reduce GHG emissions

The fuel life cycle considers all the stages necessary to reach its final consumption, from obtaining the raw material to its final use in the aircraft (commonly called "well-to-wheel"). GHG emissions are generated during each of these stages. SAF could reduce these full life cycle emissions by up to 99% compared to fossil fuels (Figure 2) since SAF production allows a portion of emissions to be reabsorbed or avoided during the life cycle.

Figure 2. Life cycle of sustainable fuels. *Source: Roundtable on Sustainable Biomaterials, RSB 2022*[16].



[16] SAF Sustainability Guidance for Airports, RSB, 2022.

3

Raw materials and conversion processes

There are different processes and technologies to produce SAF. Some of them are approved by the American Society for Testing and Materials (ASTM) while others are under evalation. Currently, 11 processes are approved by ASTM[17] through its reference standards D7566 and D1655, which establish the quality specifications that SAF must meet and their blending ratios. Among the SAF production processes already approved are: Fischer-Tropsch (FT), alcohol-to-jet (AtJ), hydrotreated esters and fatty acids (HEFA), and co-processing (Table 1). Each process has specific types of raw materials that can be used, ranging from cellulosic biomass, cooking oils, and municipal solid waste to sources with high decarbonization power, such as green hydrogen and captured carbon.

Table 1. Approved conversion processes, raw materials, and potential reduction of GHG emissions in relation to jet fuel fossil. *Source: Modified from Clean Skies for Tomorrow. Sustainable Aviation Fuel Policy Toolkit, World Economic Forum, 2021. Note: HEFA: Hydrotreated esters and fatty acids.*

	Raw material	Evaluation of opportunities	Technological maturity	Reduction of GHG emissions in the life cycle vs. fossil jet fuel.
HEFA	Lipid waste and used oils, and plants cultivated for energy production[(a)], transportable and with pre-existing supply chains.	Secure, proven and scalable technology. Potential to meet 5% to 10% of jet fuel demand.	Mature.	70%-85%[(b)].
Alcohol-to-Jet[(c)]	Agricultural and forestry waste, urban solid waste[(d)], energy crops grown for cellulose[(e)]. Great availability of cheap raw materials, but the collection is disaggregated.	Technology developed, with the first commercial projects already in March. Great potential in Latin America, where ethanol production already exists.	Developed, commercial scale engineering projects underway.	75%-95%[(f)].

[17] SAF conversion processes, ICAO

		Raw material	Evaluation of opportunities	Technological maturity	Reduction of GHG emissions in the life cycle vs. fossil jet fuel.
Biomass to SAF Pathways	**Gasification + Fischer-Tropsch**	Agricultural and forestry waste, municipal solid waste[d], and energy crops grown for cellulose[e]. Great availability of cheap raw materials, but disaggregated collection.	Medium-term potential. Technical challenges in biomass gasification. More flexible range of fuel products[g].	Developed, commercial scale engineering projects underway.	80%-90%.
	Gasification + Methanol-to-Jet		Medium-term potential. Technical challenges in biomass gasification. High selectivity to SAF[h].	Developed, commercial scale engineering projects underway (ASTM certification pending).	80%-90%.
	Pyrolysis + Upgrading		Pyrolysis technologies proven on a commercial scale, with improvements in development, to be tested in 2027+.	In development (ASTM certification pending).	75%-85%.
Power-to-Liquid	**Carbon Capture + Fischer-Tropsch**	Renewable electricity, H_2 and CO_2. Unlimited potential by directly capturing CO_2 from the air. CO_2 capture from point sources as a transition technology.	Commercial-scale projects underway by 2027+, primarily in areas with high potential for low-cost electricity generation. More flexible range of fuel products[g].	Developed, commercial scale engineering projects underway.	85%-99%[i].
	Carbon Capture + Methanol-to-Jet		Commercial scale projects underway by 2027+, mainly in areas with great potential for low-cost electricity generation. High selectivity to SAF[h].	Developed, commercial scale engineering projects underway (ASTM certification pending).	85% -99%[i].

a. Trees that produce oilseeds on degraded land with low indirect land-use change or as oilseed rotation crops. b. Excludes all edible oilseed crops. c. Production of SAF through ethanol. d. Used mainly for the production of SAF via Fischer–Tropsch (FT) gasification. e. As coverage and rotation crops. f. Excludes all edible sugars. g. FT process considers products such as jet fuel, diesel and naphtha, among others. h. In an industrial process, selectivity is understood as the fraction of product formed and the transformed amount of one of the components. i. Up to 100% with a totally decarbonized supply chain.

The most widely used process is currently HEFA which mainly uses used cooking oils as raw material. It is anticipated that approximately 85% of the SAF volume produced in the next five years will come exclusively from this process[18].

Notably, the process of producing SAF yields additional products, generating added value for the industry.

[18] Press Release N°34, IATA, 2023

4 Sustainability criteria

Different institutions have established a series of criteria to ensure that the fuel is sustainable. Among the requirements are that SAF must significantly reduce emissions compared to fossil fuels (a CORSIA-eligible fuel will achieve net GHG reductions of at least 10%, compared to the reference values of aviation fuel life cycle emissions[19]). In addition, a SAF cannot be produced from crops on land with high carbon reserves or that cause deforestation, and their impact on biodiversity must be minimized, among others.

Some examples of raw materials with the potential to meet these sustainability criteria would be used cooking oils, forestry waste, urban waste, and carbon captured directly from the air.

5 Environmental, economic, and social benefits

In addition to the main benefit of using SAF, which is the decarbonization of aviation, the consumption of these fuels would also reduce emissions of other pollutants such as sulfur dioxide and particulate matter[20], compared to the use of fossil fuels. Furthermore, the development of the SAF industry would allow certain productive sectors to develop locally, generating important economic and social effects in areas where the industry is based, in addition to promoting decentralization.

[19] *CORSIA Sustainability Criteria for CORSIA Eligible Fuels, ICAO, 2022.*

[20] *Lukas Durdina et al. (2021). "Reduction of Nonvolatile PM Emissions of a Commercial Turbofan Engine at the Ground Level from the Use of a SAF Blend".*

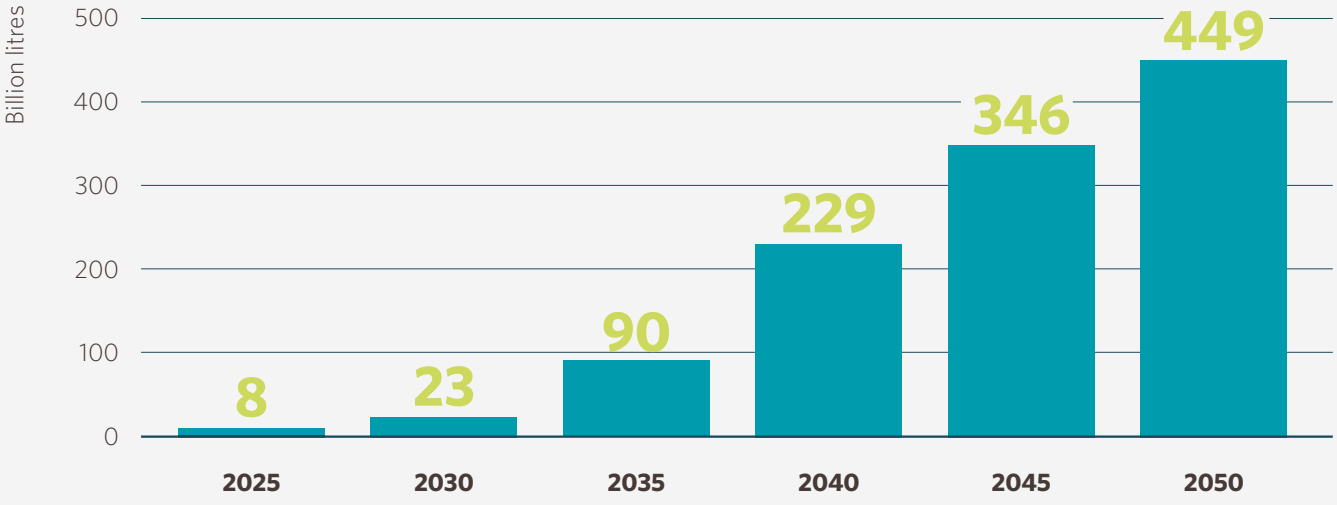
2.2.
SAF production capacity worldwide

Currently, different industries are making efforts to increase the production and consumption of SAF. In 2023, SAF production exceeded 600 million liters, doubling previous year's production. It is estimated that in 2024 SAF production will triple to represent 0.53% of jet fuel demand[21].

Even though the price of SAF is higher than conventional jet fuel, airlines are moving towards purchasing agreements with SAF suppliers. This is reflected in the increase in the volume of SAF contracted by the airlines, which went from 9 billion liters in 2021 to 21.7 billion liters in 2022[22]. This shift is also seen in the increase in commercial flights using these fuels, which rose to more than 700.000 between 2011 and 2023[23].

According to the International Air Transport Association (IATA), to achieve the goal of net-zero carbon emissions by 2050, SAF production would need to reach 449 billion liters by that time (Figure 3). Important technological advances are thus necessary, along with significant development in infrastructure for the entire value chain of these fuels[24].

Figure 3. Demand projection for SAF to achieve net-zero emissions by 2050. *Source: International Air Transport Association, Net Zero 2050, Sustainable Aviation Fuels: Factsheet.*



[21] Press Release N°69, IATA

[22] SAF Offtake Agreements, ICAO.

[23] Sustainable Aviation Fuel, Aviation Benefits.

[24] Net zero 2050: sustainable aviation fuels - Fact Sheet. IATA, 2023.

2.3. International treaties and agreements for GHG emission reduction

In 2015, at the 21st United Nations Climate Change Conference (COP21) in Paris, world leaders agreed on commitments to reduce carbon emissions through the **Paris Climate Agreement**[25].

Additionally, at the 41st ICAO General Assembly in 2022, the Long-Term Aspirational Goal (LTAG) was adopted with the global aim of **achieving net-zero carbon emissions by 2050**, in line with the commitments of the Paris Agreement. To achieve this, the assembly asked Member States to take a coordinated approach regarding policies and investment to accelerate the research, development, and use of cleaner and renewable energy sources for aviation, including SAF[26], taking into consideration local circumstances. Furthermore, the resolution urges Member States to prepare or update their Action Plans for the Reduction of CO_2 Emissions from International Aviation, and to present them to the ICAO, if possible, by the end June 2024.

Similarly, in November 2023, at the CAAF/3, a global framework was developed to promote the clean energy transition in international aviation. Within this framework, in order to support the achievement of the LTAG, ICAO and its Member States "strive to achieve a collective global aspirational Vision to reduce CO_2 emissions in international aviation by 5% by 2030 through the use of SAF, Lower Carbon Aviation Fuels (LCAF) and other cleaner sources of energies for aviation, compared to zero cleaner energy use scenario"[27]. The framework takes into consideration the special circumstances and respective capacity of each Member State to contribute to achieving the objective while still promoting the production of SAF in all geographies.

Finally, the promotion of the use of SAF in aviation is fully aligned with what was agreed upon in December 2023 at the 28th United Nations Climate Change Conference (COP28) in Dubai, where an agreement was reached that seeks to abandon the use of fossil fuels by 2050[28].

For its part, Chile is part of the Paris Agreement and has adhered to the LTAG, as well as other global commitments that have served as a basis for defining its environmental plans and strategies. These commitments have allowed Chile to work on measures that mitigate the effects of climate change for all the country's productive sectors, including air transport, a responsibility that supports the preparation of this SAF Roadmap.

2.3.1. Public policies for the use of SAF in other countries

At the international level, various plans and strategies have been developed to address the impact of the aviation industry on climate change, both for international and domestic air transport. These efforts are supported by the basket of measures proposed by organizations such as the ICAO, as mentioned above, which includes the promotion of the use of SAF.

[25] *Paris Agreement. United Nations, 2015*

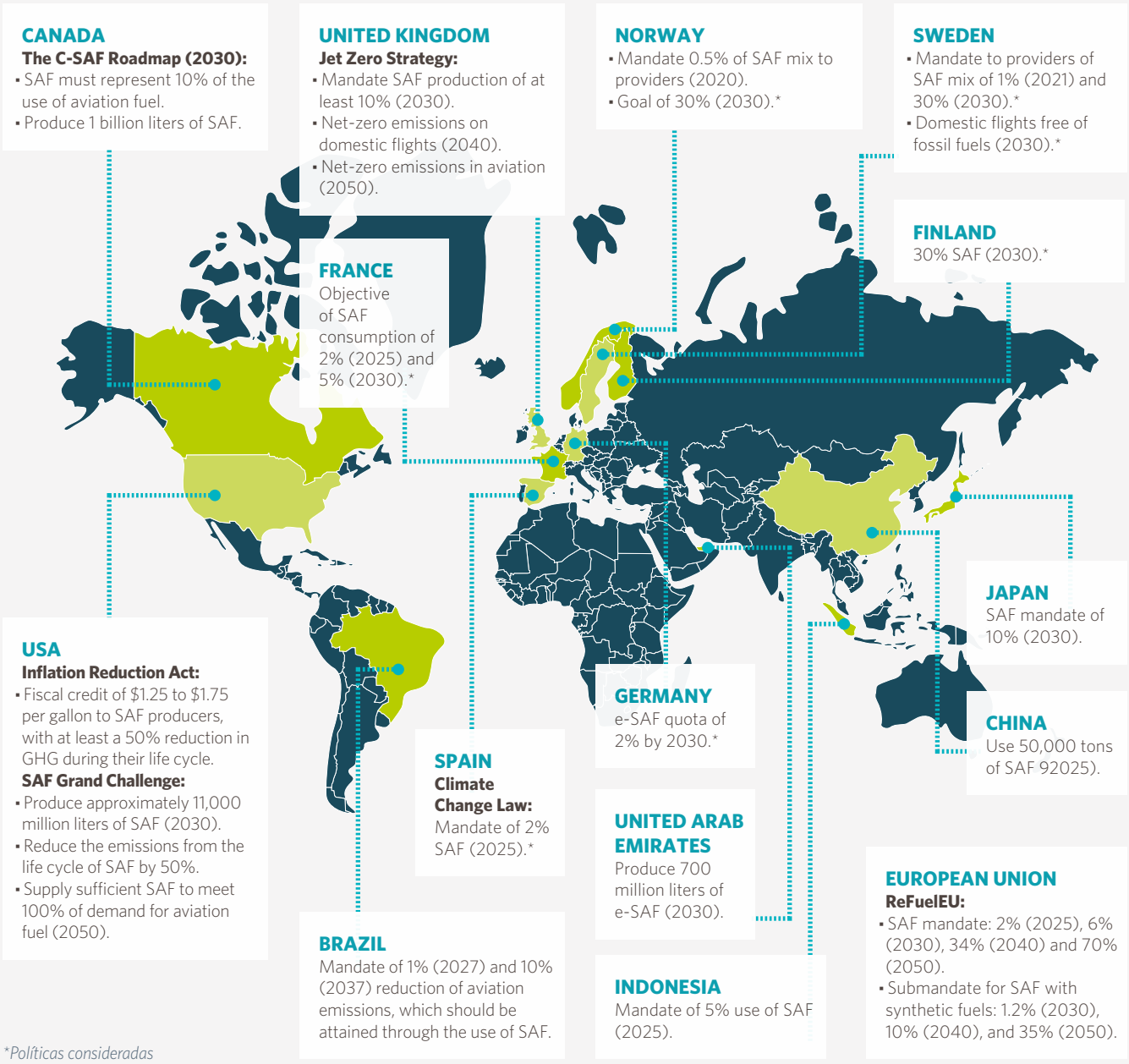
[26] *Resolution A41-21, ICAO.*

[27] *Global Framework on SAF, LCAF and other cleaner sources of energy for aviation, CAAF/3, ICAO, 2023.*

[28] *First World Balance. COP28, 2023.*

Typically, some of these policies establish **incentives** for the research, development, and production of SAF, while others set specific goals to be achieved within a certain time. Some policies may also include **mandates** that establish an obligation for air operators or fuel suppliers concerning a specific task or SAF use **goals**. The policies have different objectives, including reducing uncertainty for private investors, promoting the generation of a market, and getting different industries to join forces for the energy transition. Some of the international policies that currently stimulate the production and increase in demand for SAF are detailed in Figure 4.

Figure 4. SAF policies around the world. *Source: Prepared by the authors.*



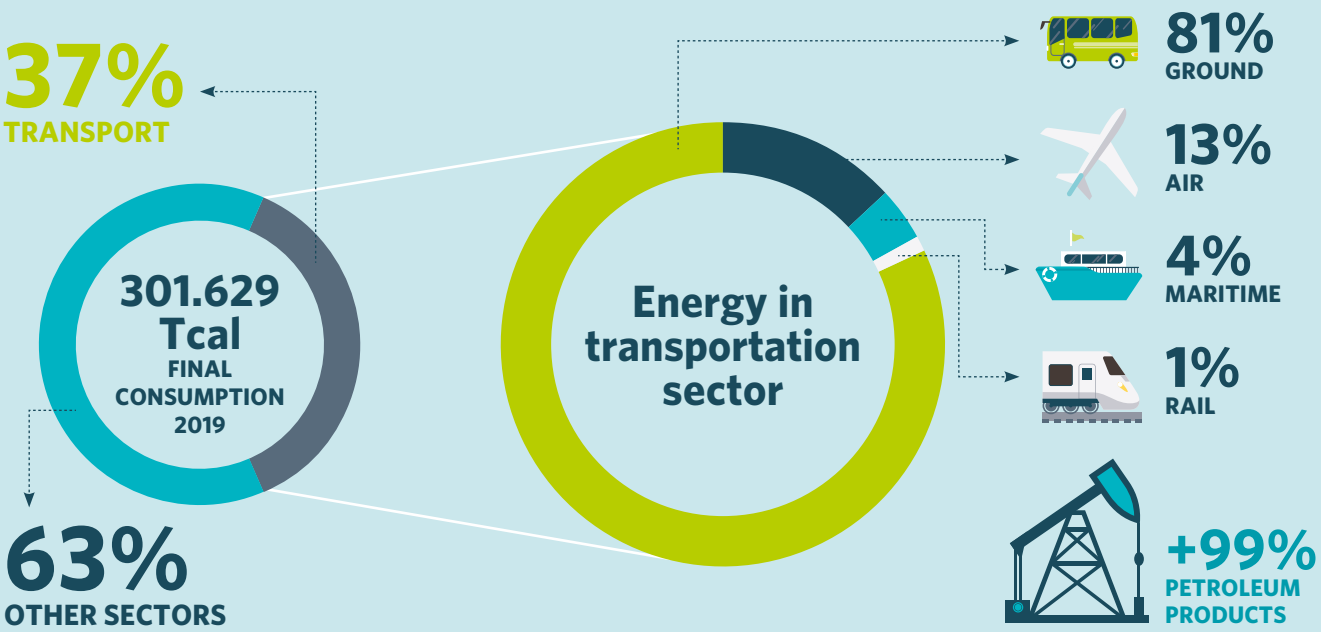
**Políticas consideradas dentro del RefuelEU*

2.3.2. National perspective

Fuel consumption in air transport

According to data from the National Energy Balance, in 2019 (the year before the COVID-19 pandemic) Chile's total energy consumption reached 301,629 Tcal, and 37% of that consumption was by the transportation sector, within which the air sector represents 13% (Figure 5)[29].

Figure 5. Energy consumption in Chile, 2019. *Source: Ministry of Energy National Energy Balance.*



Currently, in Chile, all of the aviation fuel consumed is of fossil origin, whether imported directly as fuel or produced locally from the refining of crude oil. Sales of conventional jet fuel increased by the equivalent of 6.6% annually over the decade before the COVID-19 pandemic. Thus, sales of this fuel doubled in the 11 years between 2008 and 2019, reaching a historical maximum of 1.6 billion liters in 2018[30], with a subsequent drop due to the pandemic (Figure 6).

Based on estimates by the SAF Roundtable Advisory Team, comprised of representatives of the MTT, MEN, AgenciaSE, ENAP, and the IDB, it is projected that even considering energy efficiency measures, aviation fuel consumption in Chile could increase by 129% between 2019 and 2050 (Figure 6). That projection is reinforced by the projected growth in passenger demand[31], which is attributed to factors such as greater accessibility of this transport mode and the country's distance from major hubs.

In terms of GHG emissions from air transport, Chile contributed 0.3% of global emissions in 2017, a percentage that has remained stable in recent years[32].

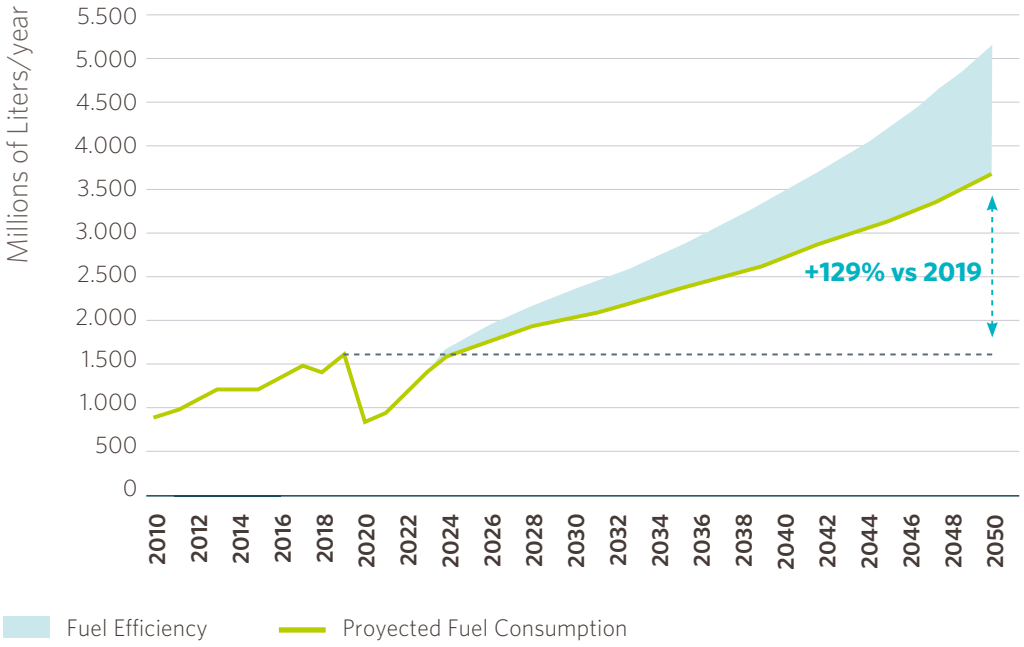
[29] *National Energy Balance 2019, Open Energy.*

[30] *Sale of liquid fuels, Open Energy.*

[31] *Strategic Plan for Air Transport. Civil Aeronautics Board, 2020.*

[32] *Action Plan to Reduce GHG Emissions from International Civil Aviation, DGAC, 2022.*

Figure 6. Previous and projected aviation fuel consumption in Chile. *Source: Prepared by the authors.*



It is projected that by 2050, jet fuel consumption in Chile **will increase to more than double what was consumed in 2019.**

Public policies with an impact on the decarbonization of air transport

In March 2022, Chile presented its Action Plan to Reduce GHG Emissions from International Civil Aviation to the ICAO[33]. The report details both actions already implemented and those currently being undertaken by the country to decrease GHG emissions.

Among the national public policies with an impact on the decarbonization of air transport, the Long-Term Climate Strategy (LTCS) of the Ministry of the Environment stands out as key. The LTCS considers the reduction of emissions from air transport, in addition to the country's participation in global agreements for this purpose. Within its Objective 1 ("To achieve a low-carbon energy matrix by 2050"), the strategy establishes that there will be a 20% reduction of direct GHG emissions from the use of fuels in the transport sector (including land, sea, and air transport) by 2040 and a 40% reduction by 2050, compared to 2018.

Among the Ministry of Energy's policies, pertinent is the National Energy Policy[34] (PEN, by its acronym in Spanish), updated in 2022. Its General Objective 1 focuses on an energy matrix low in GHG emissions. Among the goals of the PEN, in accordance with the goals set by the LTCS, is to achieve at least 70% zero-emission fuels by 2050 in non-electric final energy uses. Furthermore, General Objective 4 of the PEN refers to sustainable transportation and proposes promoting the incorporation of zero-emission fuels for the different modes of transportation, which would include air transportation, and ensuring the necessary infrastructure for the implementation of the objective.

Added to these initiatives are others such as the National Green Hydrogen Strategy and the Green Hy-

[33] *Ibid.*

[34] *National Energy Policy. Ministry of Energy, 2022.*

drogen Action Plan 2023–2030. The latter proposes an energy transition and the reduction of emissions from various sectors of the economy, including aviation, through the use of fuels derived from hydrogen. Furthermore, the plan proposes that Chile advance as a global supplier of clean energy, diversifying the export market through synthetic fuels in the case of air transport.

Finally, other national policies, such as the Extended Producer Responsibility Law, the Chile 2040 National Organic Waste Strategy[35], and a proposed bill that promotes the valuing of organic waste and strengthens waste management at the territorial level, could be related to the decarbonization of aviation from the standpoint of energy recovery from residues.

Role of SAF in decarbonizing aviation in Chile

Although there are other technologies to decarbonize the aviation industry, such as electrification or the use of hydrogen, their use in the short and medium term would be limited to small aircrafts and short-distance flights. For larger aircrafts that make long-distance flights, the use of SAF is essential (Table 2).

Due to the geographic characteristics of Chile and the business model that prevails, the highest concentration of passengers travel on medium- and long-distance flights (52% and 45%, respectively). Therefore, the use of SAF appears to be a necessary measure and one that is essential to meet the country's decarbonization objectives.

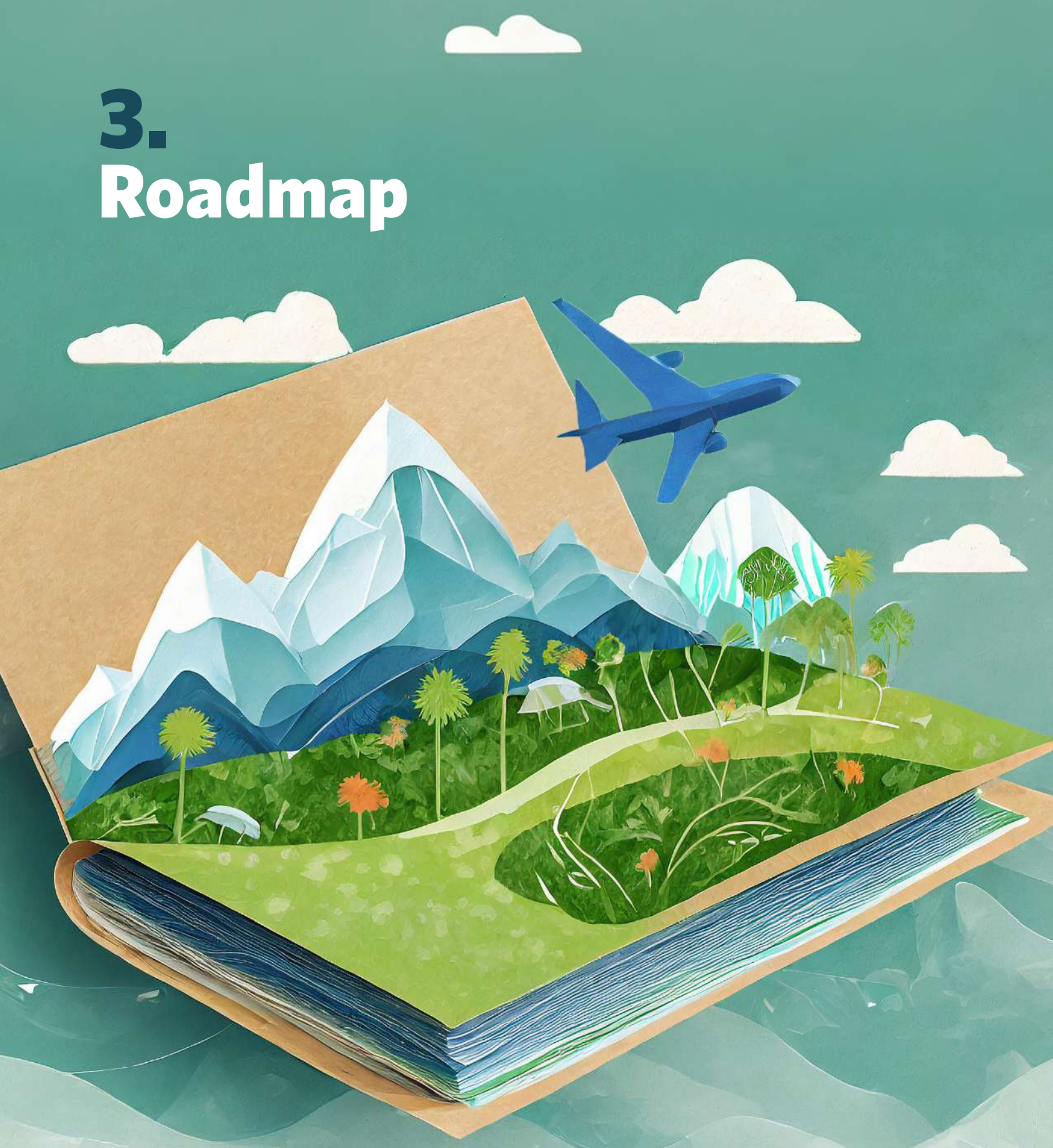
Table 2. Uses of new energy for aviation by fight category and market share in Chile. *Source: Air Transport Action Group, Waypoint 2050 (2021); and statistics from the Civil Aeronautic Board.*

Tipe of Flight	2020	2025	2030	2035	2040	2045	2050	Passenger participation in Chile, 2019
Commuter	●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	**~0%**
Regional	●	●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	**~0%**
Short-haul	●	●	●	● ●	● ●	● ●	● ●	**3,6%**
Medium-haul	●	●	●	●	● ●	● ●	● ●	**51,8%**
Long-haul	●	●	●	●	●	●	●	**44,7%**

● SAF ● Hydrogen fuel cell ● Hydrogen ● Potencially hydrogen ● Electric

[35] *National Organic Waste Strategy - Chile 2040. Ministry of the Environment.*

3. Roadmap



3.1. SAF Roundtable

To align the interests of various sectors in developing actions and policies to promote the decarbonization of aviation in Chile, the Clean Flight program established by the Sustainable Energy Agency and the Civil Aeronautics Board of the Ministry of Transport and Telecommunications, together with the IDB and the Ministry of Energy, launched a public-private working group for the development of SAF in Chile. The **SAF Roundtable** is a voluntary advisory body that brings together various stakeholders in the aviation fuel value chain. Its purpose was to gather key background data on the industry to allow for the **preparation of Chile's first SAF Roadmap.**

SAF Roundtable's roles

Advisory Committee
Responsible for participating in the Public-Private SAF Roundtable sessions and providing technical support, with the objective of establishing the guidelines to generate the SAF Roadmap.
Participants: AgenciaSE, MTT, MEN, ENAP, and IDB.

SAF Roundtable Coordinating Entity
Manages compliance with the objectives of each session of the Public-Private SAF Roundtable. Systematizes the resulting information and prepares its minutes.
Participants: IDB and Clean Flight Program.

Public-Private SAF Roundtable
Convened to collect input and suggestions from interested parties regarding the development of SAF in Chile.
Participants: All stakeholders.

In total, five sessions of the **Public-Private SAF Roundtable** were held, with participants including air operators; airline, forestry, biomass and hydrogen associations; potential producers, distributors, and importers of SAF (such as fuel companies); airport concessionaire companies; aircraft manufacturers; academic institutions and representatives from other countries and regions; and pioneers in the field (see the Appendix). All sessions included presentations by attendees and discussions involving more than 60 companies and organizations (Figure 7)[36].

[36] *SAF Table meeting minutes, Clean Flight Program.*

Figure 7. Entities participating as presenters at the SAF Roundtable. *Source: Prepared by the authors.*

This process gathered views and presentations shared by the participating entities at the roundtable, highlighting the importance of a collaborative approach to promote more sustainable aviation and energy production in Chile. With these inputs, the first version of the SAF Roadmap was prepared, which was validated and strengthened with the observations made through a public consultation process.

Stages of preparation of the SAF Roadmap 2050

Through the different stages of the process of preparing the SAF Roadmap, the visions of both the transportation and energy sectors were identified, as discussed in the next section.

3.2. Perspectives of the Transport and Energy Sectors

Transportation Sector

The potential users of SAF, airlines, have developed sustainability initiatives that are within their reach, such as energy efficiency, operational improvements, and fleet changes. However, these measures are not sufficient to achieve net zero emissions by 2050. Therefore, airlines operating in Chile have indicated the **need to develop a SAF market,** and some have even already established goals for its use for the airlines in the years ahead.

However, **they have emphasized that the acquisition of sustainable fuels should not generate major economic impacts and should be achieved within a regulatory framework consistent with the global scenario,** as these costs could later be passed on to passengers.

Energy Sector

Companies linked to the production, import, and distribution of fuels have shown interest in the SAF industry that could potentially be developed. They have also pointed out that they have plans to contribute to Chile's energy transition, given the climate commitments assumed by the country. The companies have indicated that the production and/or distribution of SAF is aligned with these objectives, and have highlighted that, **with the appropriate incentives, the local market could be supplied with SAF** in the short and medium term. Among the aspects mentioned by this sector are **the need to make the availability of raw materials more visible, to study the feasibility of the Chilean SAF market, to adapt a regulatory framework and to establish mechanisms to access capital for investment in SAF production.**

During the Public-Private SAF Roundtable sessions, multiple ways to promote this industry in Chile were discussed. However, it was emphasized that it is first necessary to work on reducing the various gaps and barriers (see Section 3.4) that make large-scale local production of SAF impossible today and that public-private coordination is required to **generate market-enabling conditions.**

3.3. SAF development opportunities in Chile

Because of its geographic and climatic characteristics, Chile has positioned itself as a global leader in the development of renewable energy. These conditions have allowed the country to promote a series of initiatives to pursue decarbonization of the energy matrix. Chile has a considerable amount of renewable energy resources that could potentially reach a total accumulated energy of more than 1,800 GW, and the government's motivation for the development of these energy sources is further supported by the low costs associated with producing renewable energy through resources such as solar (central-north zone) and wind (southern zone), compared to other regions of the world[37].

Chile also has multiple ecosystems and a diversity of raw materials, both biological and non-biological, that allow for exploring different conversion processes for SAF development. Comments from SAF Roundtable participants alluded to the different raw materials that present opportunities to produce these fuels in Chile, including:

Used cooking oils: there are companies in Chile that operate by collecting used cooking oils from industries that use them in their production processes. The collected oil is mainly exported for subsequent use in the production of biofuels, among other uses. There is potential to recover these oils at the source where they are generated (e.g., restaurants), and then use them for local SAF production. Furthermore, it is possible to review the incorporation of this waste in the Extended Producer Responsibility Law as a priority product, which could boost this industry.

Forest biomass: this raw material has multiple uses in Chile, ranging from construction to heating, with the latter focused mainly on the southern part of the country. Although the high demand for this biomass has resulted in limited availability, the forestry industry unions state that improved plans for forest residue management would allow for an expansion in its supply.

Biomass with high lipid content: examples of these raw materials that have high conversion potential and do not compete with the food industry include microalgae, atrophy, halophyte, and camelina[38]. Depending on their characteristics, they can grow in the sea, inland, in the desert, and/or in semi-arid areas. The variety of climates in Chile presents an opportunity to explore these raw materials.

[37] *National Green Hydrogen Strategy. Ministry of energy.*

[38] *Begginer's Guide to SAF, ATAG, 2023*

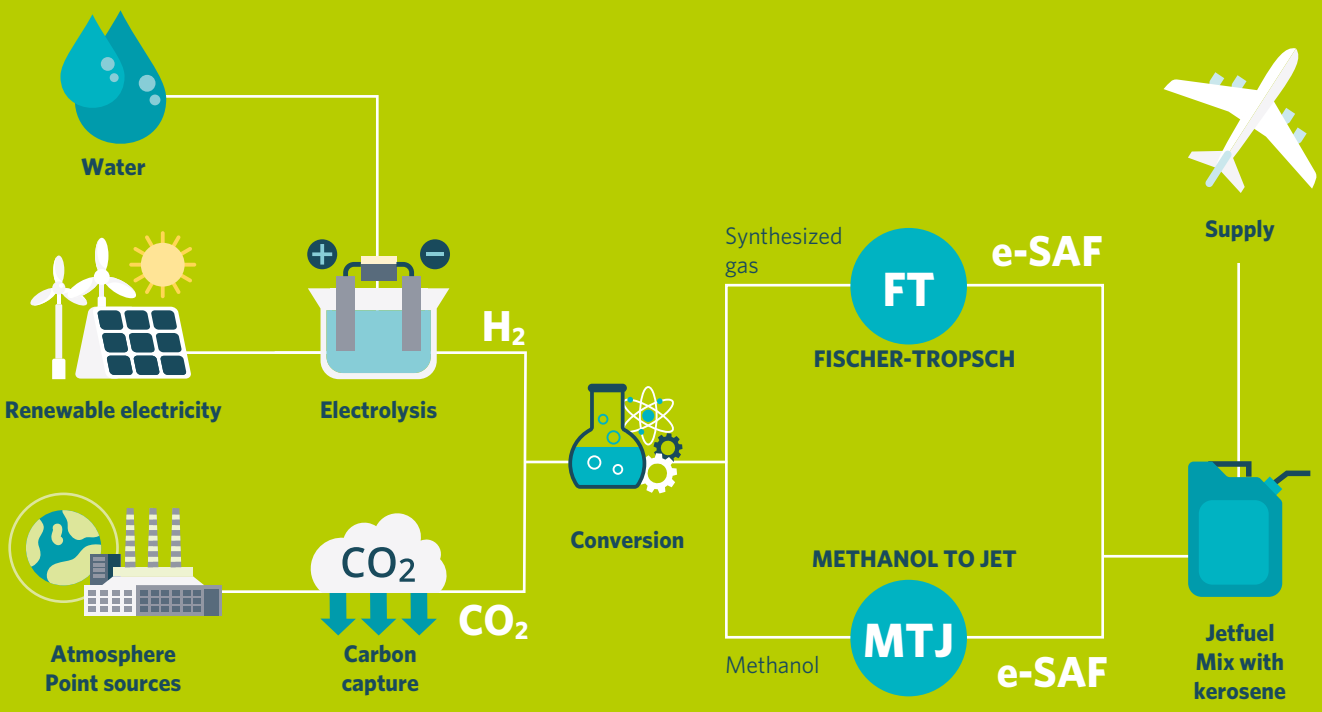
Green hydrogen: among the multiple applications of green hydrogen is the production of synthetic fuels, or e-fuels, through Power-to-Liquid processes. With its high renewable energy potential, Chile has advantages in the generation of green hydrogen, as reflected in the National Green Hydrogen Strategy.

3.3.1. SAF derived from green hydrogen (e-SAF)

As noted above, e-fuels are synthetic fuels produced through the power-to-liquid process, which uses green hydrogen, a carbon source (e.g., CO_2), and renewable electricity to produce liquid hydrocarbons, including SAF. Green hydrogen can be obtained through the electrolysis process, in which water molecules are exposed to electrical currents from renewable energy. The required CO_2 can be captured from point sources or directly from the air[39].

The power-to-liquid process encompasses multiple possible pathways to produce e-fuels, among them the Fischer-Tropsch process, a technology approved by the ASTM to produce SAF, and the methanol-to-jet process, which is under review for its ASTM (Figure 8). When SAF is produced in these ways, it is called e-SAF.

Figure 8. Production and supply phases of e-SAF. *Source: Prepared by the authors.*



[39] *Power-to-Liquids A scalable and sustainable fuel supply perspective for aviation. German Environment Agency, 2022.*

3.3.2. E-fuels in the National Green Hydrogen Strategy and the Green Hydrogen Action Plan 2023–2030

The National Green Hydrogen Strategy establishes Chile's ambitions to create a new industry, with one of its key objectives being to be able to export hydrogen and its derivatives starting in 2030, including e-fuels for aviation (Phase III).

Phase I of the implementation of the strategy is being carried out from 2020 to 2025. It consists of activating the domestic industry and developing exports[40]. The aim is to encourage initial investments that should translate into pilot or demonstration plants. From 2023 until 2030, the Green Hydrogen Action Plan will define the roadmap for the deployment of this industry.

One of the axes of the National Green Hydrogen Strategy is to position Chile internationally as a producer of clean fuel. In this context, agreements have been signed with the United States, France, Germany, and Japan, as well as with the World Bank, to generate partnerships in this area.

It should be noted that in Chile there are already pilot projects focused on the production of green hydrogen and e-fuels, and that some of them have advanced quality control centers and carry out R&D+I activities. Thus, there is an opportunity for these projects to broaden their range of possible products, for example allowing them to move forward in the production of e-SAF.

[40] *National Green Hydrogen Strategy, Ministry of Energy.*

3.4. Challenges for the development of SAF in Chile

Despite the many benefits of the SAF value chain, such as GHG emissions and waste reduction, as well as job creation, there are multiple complexities involved in its development. The Public-Private SAF Roundtable identified seven challenges for the development of SAF that are in line with what was expressed by various international organizations[41,42].

Limited information regarding the availability and potential of raw materials for SAF production

Each type of SAF conversion process entails different specific infrastructure, production areas, logistical requirements and production costs[43]. This points to the essential need to have **information regarding the availability and feasibility of raw materials for the production of SAF.**

Competition over the use of the raw materials required for SAF production

The production of SAF is expected to compete with other uses, such as the production of other energy sources, for the availability of raw materials. For example, used cooking oil is utilized for biodiesel production, green hydrogen to synthesize ammonia, and forest biomass for heating and electricity generation, as well as animal foraging and shelter. However, it is important to recognize that aviation has fewer pathways for decarbonization than other transportation modes. Therefore, a mechanism could be established to prioritize the use of certain raw materials, especially those that are most competitive for the use of SAF production.

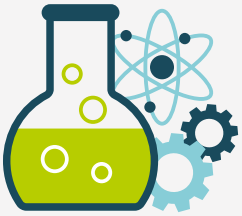
[41] Clean Skies for Tomorrow: Sustainable Aviation Fuel Policy Toolkit, World Economic Forum, 2021.

[42] Sustainable aviation fuel, ATAG.

[43] Fueling Net Zero. ICF Report for ATAG Waypoint 2050, 2021.

Higher production cost of SAF compared to conventional jet fuel

When considering the expenses associated within the SAF value chain, costs tend to be high, as is the case with raw materials and their transport and storage. Added to this is the high cost of SAF production technology and the fact that greater investment is required to achieve economies of scale. **This results in the production cost of SAF being higher than that of conventional jet fuel.**



Low level of technological maturity to scale SAF production

Given that the technology for the different SAF production processes is still in the experimental phase (except in the case of some technologies such as HEFA[44]), the higher cost of SAF production is exacerbated by the **low degree of maturity of the technology, in turn affecting the scalability of production.**

Lack of specialized knowledge in the SAF value chain

Since there is currently no industry of this type in Chile, there is **no technical capacity and advanced human capital to operate future production plants.** In addition, there is almost no investment in R&D to finance training, particularly in technical and higher-level training centers.

Absence of national regulations to ensure product quality and the safety of facilities in the SAF value chain

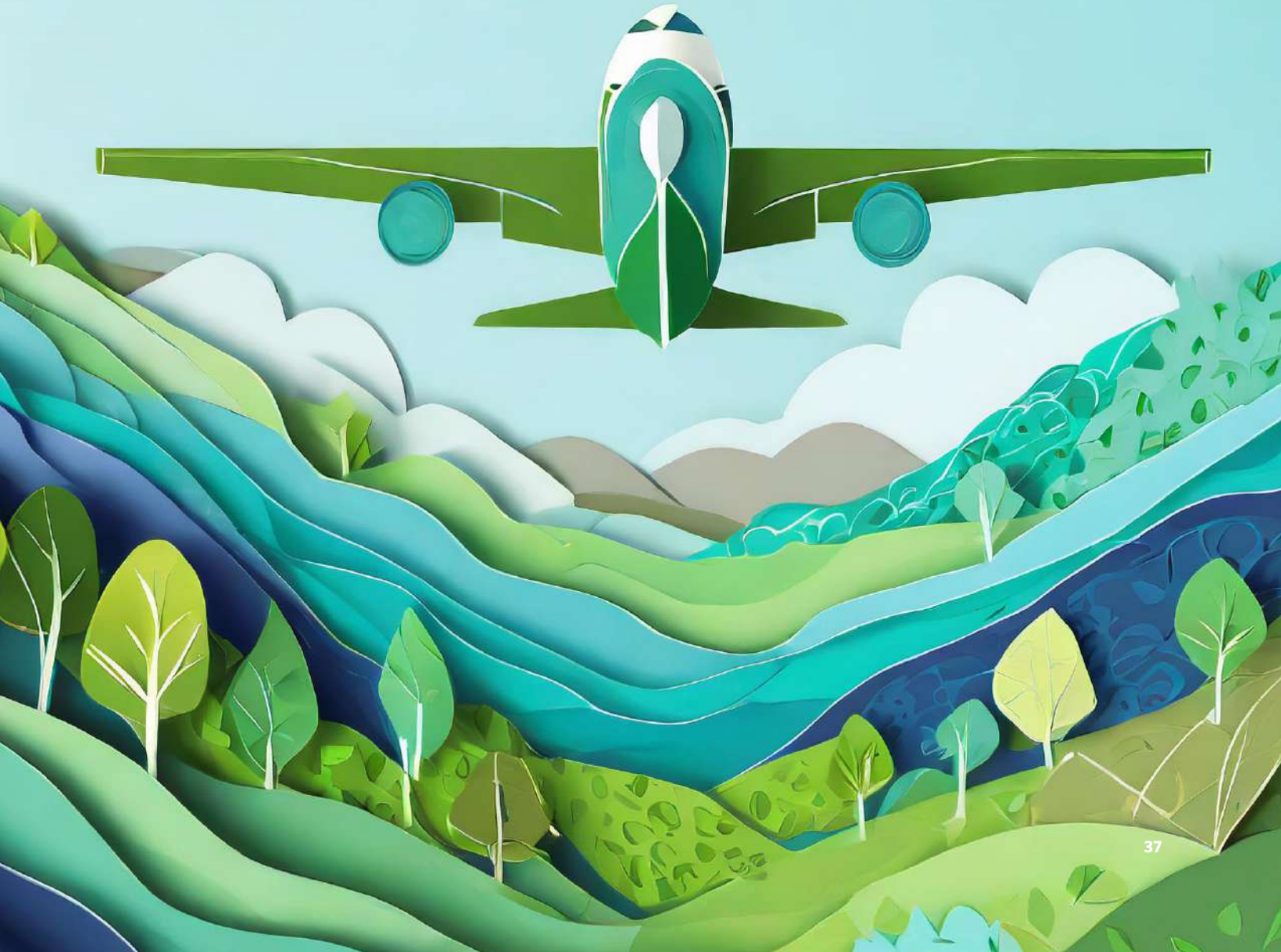
The lack of development of this industry in Chile, including its logistical aspects, **has meant there has not been the need for regulatory work associated with the safety of the facilities within the SAF value chain, nor concerning the quality specifications that these fuels should have.** Therefore, the establishment of this industry in Chile will require the development of regulations to allow its safe operation.

[44] *Okolie et al. (2023). "Multi-criteria decision analysis for the evaluation and screening of sustainable aviation fuel production pathways".*

Need for enabling conditions for SAF certification throughout its life cycle

for SAF to be commercialized it must meet specifications associated with its life cycle and sustainability criteria, for which there are international verification methodologies. However, since there is no SAF market in Chile, current conditions are not in place to verify and certify these specifications, **resulting in uncertainty regarding the timely availability of a SAF certification scheme**.

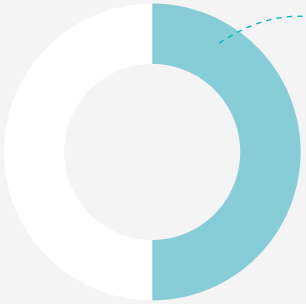
Many of the challenges mentioned above result in the **current limited international supply of SAF.** Due to this limited supply, some of the SAF-producing companies have declared that, as of now, their production is already committed for the short and medium term.



3.5.
The way forward for decarbonizing aviation in Chile

The public-private participatory process of the SAF Roadmap resulted in the development of a structure with five **axes**, each of which deploys **guidelines** and **actions** aimed at achieving the **usage goal for SAF by 2050**. That goal is in line with the different national energy strategies and policies, as well as with other international global commitments that aim to mitigate the effects of climate change. The structure addresses the gaps pointed out during the SAF Roundtable and proposes a work plan with respective actions in the coming years.

The objective of the roadmap is for SAF to represent at least **50%** of the fuel used in national and international aviation in Chile by 2050. This is an aspirational goal for using SAF to meet the expectations of the sector in the years ahead.



50%

Share of SAF used in aviation in Chile by 2050.

AXIS 1 Capacity Building

- Generate opportunities for the integration of capacity with countries in the region or pioneers in SAF production.
- Promote human capital development processes focused on the energy transition of the aviation industry.

AXIS 2 Regulation

- Make regulatory adjustments that facilitate the development of the SAF industry and allow for its safe operation, establishing international standards as a reference.
- Generate the enabling conditions to facilitate the sustainability certification of both SAF and its raw materials, ensuring compliance with international standards.

AXIS 3 Market Development

- Facilitate the growth of SAF supply.
- Stimulate demand.
- Enable the development of the SAF market.

AXIS 4 SAF Ecosystem

- Strengthen cooperation, coordination and the emergence of national and international actors.

AXIS 5 Technology

- Promote R&D+I to accelerate technological development.

For this Roadmap, three stages are defined, of which actions are established for stages 1 and 2, with a view to incorporating actions in stage 3 once the technical inputs are obtained. This will be reflected in the next updates of the SAF Roadmap, to advance in actions that will allow the achievement of the 2050 goal.

	PERIOD
STAGE 1 - PREPARATION: start on the initial research, generation of studies, establishment of regulations, identification of key resources, and creation of the foundations necessary for the development of SAF.	2024-2028
STAGE 2 - DEVELOPMENT: pursue all of the actions related to the production of SAF, such as applied research, investment in infrastructure, small-scale production, and initial testing.	2029-2035
STAGE 3 - SCALING: focus on scaling up the production and use of SAF, optimizing processes, reducing costs, and seeking total integration in the aviation industry.	2036-2050

AXIS 1
Capacity Building

The axis aims to promote the training and development of the human capital necessary for the consolidation of the SAF industry, highlighting the role of academia, in addition to promoting international collaboration and the integration of knowledge.

Actions	Organizations Involved*	Stage
Guideline 1.1. Generate opportunities for the integration of capacity with countries in the region or pioneers in SAF production.		
Enter into agreements or other instruments between Chile and countries pioneering SAF for the development and production of SAF and the exchange of experiences and technical cooperation.	Ministries of Foreign Affairs, Transport and Telecommunications and Energy.	Stage 1: Preparation.
Guideline 1.2. Promote human capital development processes focused on the energy transition of the aviation industry.		
Identify local needs for training qualified human capital to participate in the SAF value chain (implementation of pilots, analysis of human capital requirements, among others).	Ministries of Energy and Education.	Stage 1: Preparation.
Strengthen the academic sector to develop local capabilities.	Ministries of Energy and Education.	Stage 2: Development.
Create specific job profiles for the development of SAF.	Ministry of Energy.	Stage 2: Development.
Create specific training programs for various levels and roles in the SAF value chain.	Ministry of Energy.	Stage 2: Development.

* It could include other organizations or services.

AXIS 2
Regulation

This axis aims to create a regulatory environment conducive to the development and deployment of SAF in Chile. This includes regulatory adjustments related to safety, quality, certifications, and raw materials used in SAF production. This framework must be consistent with international standards and serve as a valid approach to decarbonization, enabling Chile to participate in the global SAF market.

Actions	Organizations Involved*	Stage
Guideline 2.1. Make regulatory adjustments that facilitate the development of the SAF industry and allow for its safe operation, establishing international standards as a reference.		
Identify the regulations that need to be implemented to promote suitable development of all activities associated with the SAF industry, taking into account aspects related to the safety of facilities throughout the value chain, airport infrastructure, and raw materials, as well as fuel quality specifications.	Ministries of Energy, Environment and the Directorate General of Civil Aviation.	Stage 1: Preparation.
Establish an inter-ministerial team to address the necessary regulatory adjustments to be implemented in the SAF value chain.	Ministries of Energy, Environment, Agriculture, Economy, Development and Tourism, Finance, Transport and Telecommunications, and Public Works, and the Directorate General of Civil Aviation.	Stage 1: Preparation.

* It could include other organizations or services.

Actions	Organizations Involved*	Stage
Prepare a regulatory work plan for SAF that includes a regulatory adaptation schedule based on technological maturity and future projects. This plan shall be updated every three years.	Ministry of Energy and Transport and Telecommunications.	Stage 1: Preparation.
Align the regulatory needs of SAF with other energy and environmental policies, such as those related to the green hydrogen, biofuels, and circular economy sectors.	Ministry of Energy.	Stage 1: Preparation.
Guideline 2.2. Generate the enabling conditions to facilitate the sustainability certification of both SAF and its raw materials, ensuring compliance with international standards.		
Determine the existing gaps in Chile to monitor and comply with the standards used internationally for the certification of raw materials and sustainability of SAF.	Ministries of Energy, Environment and Agriculture.	Stage 1: Preparation.
Establish an enabling framework for the certification of raw materials and the sustainability certification of SAF (platforms, capacity to monitor the life cycle, availability of certification bodies, among others).	Ministries of Energy, Environment and Agriculture.	Stage 1: Preparation.

* It could include other organizations or services.

AXIS 3

Market Development

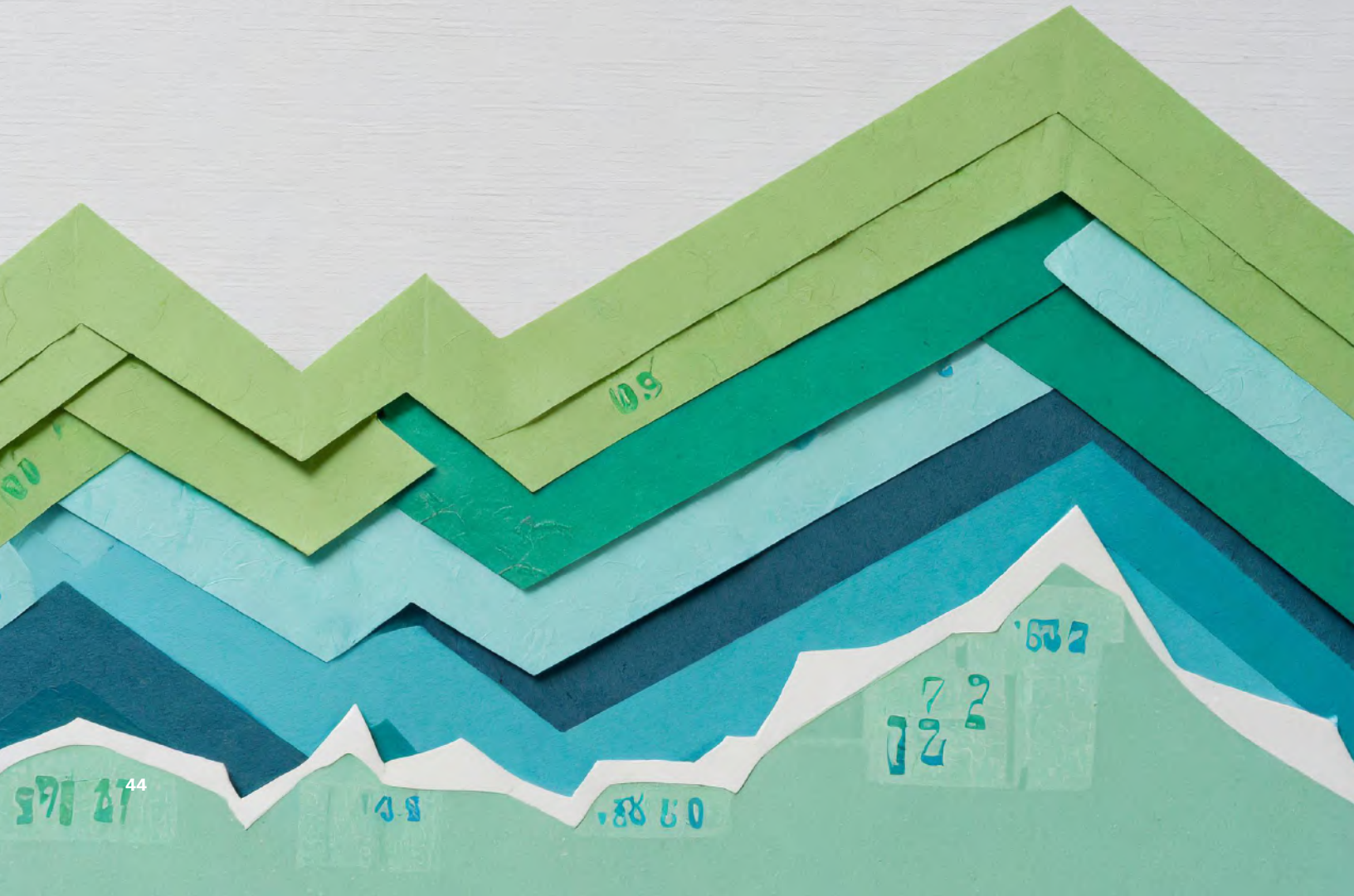
This axis aims to stimulate the growth of SAF supply and demand and enable the market for this fuel in Chile, to promote an industry aligned with global decarbonization commitments. Achieving this will require analyzing market conditions to promote better development, which will make it possible to enact policies in the coming years.

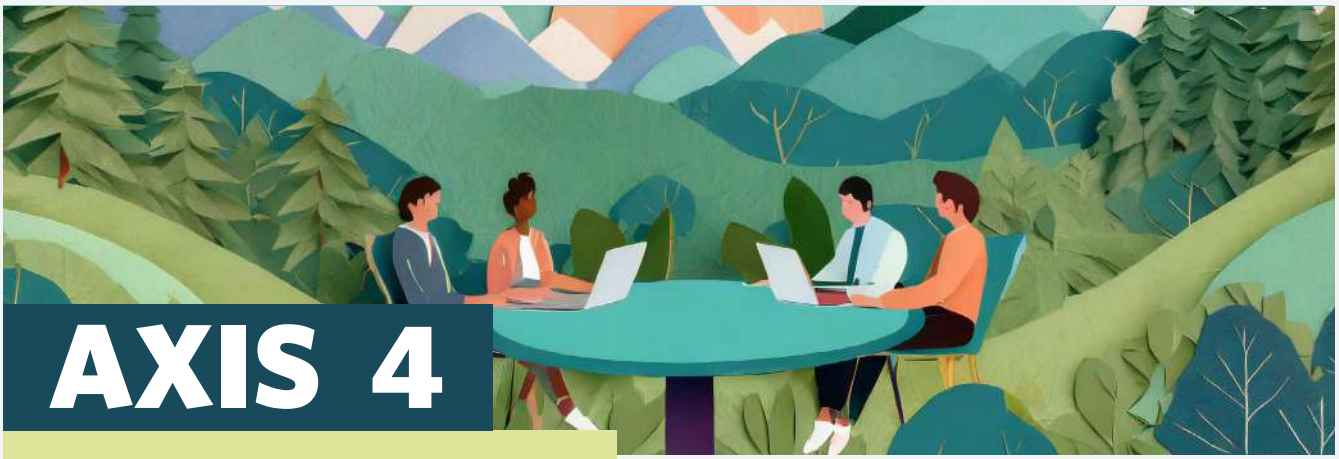
Actions	Organizations Involved*	Stage
Guideline 3.1. Facilitate the growth of SAF supply.		
Analyze public policies implemented internationally that have fostered the productive development of SAF, and evaluate their applicability in Chile (auction mechanisms, book and claim, tax credits, among others).	Ministries of Economy, Development and Tourism, and of Energy.	Stage 1: Preparation.
Establish market mechanisms to develop the productive capacity of SAF.	Ministries of Economy, Development and Tourism, and of Energy.	Stage 2: Development.
Promote the channeling of investment funds towards national SAF projects with high technological maturity and the potential to scale production.	Ministries of Economy, Development and Tourism, and of Energy.	Stage 2: Development.
Guideline 3.2. Stimulate demand.		
Evaluate and generate public policies that improve the competitiveness of SAF in Chile.	Ministries of Economy, Development and Tourism, Energy and Finance.	Stage 1: Preparation.

* It could include other organizations or services.

Actions	Organizations Involved*	Stage
Guideline 3.3. Enable the development of the SAF market.		
Collect base information to evaluate the production and/or development potential of the SAF industry (feasibility studies of production and availability of raw materials, gaps in human capital, infrastructure, environmental and social impact, among others).	Ministries of Energy, Transport and Telecommunications, Environment, and Agriculture.	Stage 1: Preparation.
Communicate internationally that Chile has the potential for the development of a SAF industry, and share information on the SAF ecosystem to attract investment.	Ministries of Foreign Affairs, and Energy.	Stage 2: Development.
Promote investment and financing mechanisms for the implementation of SAF airport facilities and infrastructure.	Ministries of Economy, Development and Tourism, Transport and Telecommunications, and Energy.	Stage 2: Development.

* It could include other organizations or services.





AXIS 4

SAF Ecosystem

This axis aims to consolidate an ecosystem of SAF industry actors in Chile, strengthening both national and international collaboration throughout the entire value chain. This will be achieved by promoting agreements, memorandums of understanding, industry partnerships, and cooperative efforts.

Actions	Organizations Involved*	Stage
Guideline 4.1. Strengthen cooperation, coordination, and the emergence of national and international actors.		
Work with associations and unions to explore paths and practices to improve market conditions.	Ministries of Energy, Agriculture and Economy, Development and Tourism.	Stage 1: Preparation.
Carry out information dissemination events to share the importance and progress of SAF.	Ministries of Energy and Transport and Telecommunications.	Stage 1: Preparation.
Identify and promote national and international agreements and alliances to promote the national SAF market, such as the Clean Production Agreements (CPA) and the ICAO's SAF assistance, capacity building, and training program (ACT-SAF).	Ministries of Energy, Transport and Telecommunications, Foreign Affairs, Economy, Development and Tourism (Sustainability and Climate Change Agency, ASCC) and Environment.	Stage 1: Preparation.
Carry out collaboration activities with national and international SAF actors.	Ministries of Foreign Affairs, Energy and the Environment.	Stage 2: Development.

* It could include other organizations or services.

AXIS 5
Technology

This axis aims to promote research, development, and innovation (R&D+I) to accelerate technological advances in the research, demonstration and pilot phases of SAF production in Chile across the value chain. This axis promotes collaboration among organizations, and in addition, the availability and procurement of funds for R&D+I projects to position Chile as a regional leader in the development of SAF.

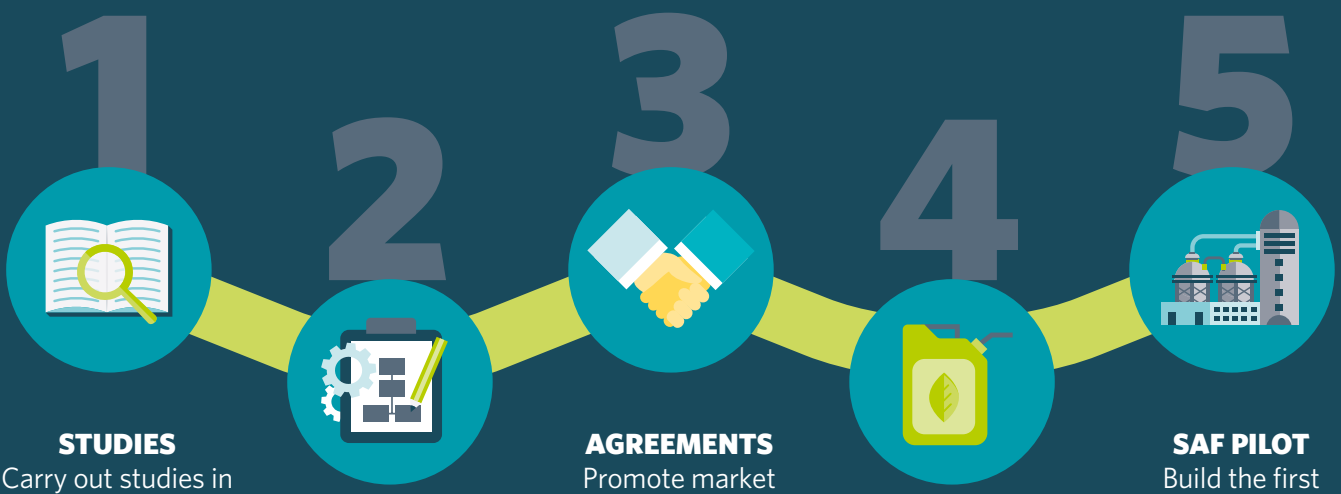
Actions	Organizations Involved*	Stage
Guideline 5.1. Promote R&D+I to accelerate technological development.		
Promote collaboration between organizations applying for R&D+I funds with other actors in the SAF industry to support their award.	Ministries of Economy, Development and Tourism (*Corporación de Fomento de la Producción*), and Science, Technology, Knowledge and Innovation (National Agency for Research and Development).	Stage 1: Preparation.
Promote the country's vision and participation in national and international discussions on SAF technological processes, in turn promoting the certification (carbon footprint, ASTM, DEF, STAN[45], among others) of developed SAF production technologies in Chile.	Ministries of Foreign Affairs (ProChile, InvestChile), Energy, and the Environment.	Stage 1: Preparation.
Coordinate the launch of competitive R&D+I funds to support SAF production processes with low technological maturity.	Ministries of Economy, Development and Tourism (*Corporación de Fomento de la Producción*), and Science, Technology, Knowledge and Innovation.	Stage 1: Preparation.
Promote implementation of demonstration projects for the production of SAF from renewable energy sources.	Ministries of Energy, Transport and Telecommunications, and Science, Technology, Knowledge and Innovation.	Stage 2: Development.

* It could include other organizations or services.

[45] *Guidance UK Defense Standardization*

3.6. First Milestones

The SAF roadmap establishes a goal for the use of SAF by 2050, identifying the guidelines and actions to achieve what in Spanish has been dubbed the deSAFío. Figure 10 presents the milestones that are relevant to the implementation of this roadmap.



STUDIES
Carry out studies in the next two years on the technical and economic feasibility of the raw materials to produce SAF in Chile, in addition to the logistics associated with SAF.

REGULATION AND MARKET
Establish a work plan to address regulatory and policy needs to produce, distribute, and consume the different types of SAF by 2026.

AGREEMENTS
Promote market development and collaboration for the production of SAF in Chile through national and international agreements.

PRODUCTION
Produce the first liter of SAF during the next three years by promoting research and development in national facilities.

SAF PILOT
Build the first SAF pilot plant before 2030 for larger scale production.

3.7. Implementation of the SAF Roadmap

Considering technological and market development in the national, regional, and international context, the first action needed is to create a governance structure that ensures the correct deployment, monitoring, and evaluation of the SAF Roadmap, which will in turn lead to new lines of action.

3.7.1. Governance

The following institutions will be part of the governance of the roadmap and will ensure the implementation and development of the guidelines and actions set out:

- Ministry of Transport and Telecommunications.
- Ministry of Energy.
- Civil Aeronautics Board.
- Energy Sustainability Agency.
- Clean Flight program.

The functions to be carried out by these institutions are the following:

Roadmap management

- Provide a global vision of the SAF Roadmap in terms of its implementation, monitoring, and evaluation.
- Act as an articulator of interested parties, both from the public and private sectors, for the implementation of the roadmap.
- Actively support the different public organizations in the implementation of the actions.
- Prepare a progress report on the roadmap that will be presented to the SAF ecosystem and published, at most, every two years after the date of this publication.
- Review this roadmap every three years proposing updates, under the responsibility of the Ministries of Transport and Telecommunications and Energy, and through the Clean Flight Program.
- Based on the results of the studies that are developed, propose intermediate milestones associated with SAF and actions for Stage 3 in future updates of the Roadmap.

Support for the development of the roadmap

- Develop general recommendations to explore opportunities for SAF.
- Develop and participate in technical roundtables on SAF.
- Identify new areas and strategic initiatives that enhance the development of SAF in Chile.
- Integrate SAF R&D+I development into other national agendas (National Green Hydrogen Strategy, LTCS, among others).

This SAF Roadmap will also require the participation of other public and private institutions that will play a key role in its implementation.

Acronyms

ACT-SAF	Assistance, Capacity-building and Training for Sustainable Aviation Fuels.
AgenciaSE	Energy Sustainability Agency.
ASCC	Agencia de Sustentabilidad y Cambio Climático (Sustainability and Climate Change Agency).
ASTM	American Society for Testing and Materials.
AtJ	Alcohol-to-Jet.
CAAF/3	Third Conference on Aviation Alternative Fuels.
CO_2	Carbon Dioxide.
COP21	21a United Nations Climate Change Conference.
COP28	28a United Nations Climate Change Conference.
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation.
CPA	Clean Production Agreements.
DGAC	Directorate General of Civil Aviation.
EASA	European Union Aviation Safety Agency.
EIA	Energy Information Administration.
ENAP	National Petroleum Company.
e-SAF	Synthetic Sustainable Aviation Fuel.
EU	European Union.
FAA	Federal Aviation Administration.
FT	Fischer-Tropsch.
GHG	Greenhouse Gases.
GLEC	Global Logistics Emissions Council.
HEFA	Hydrotreated Esters and Fatty Acids.
IATA	International Air Transport Association.
ICAO	International Civil Aviation Organization.
IDB	Inter-American Development Bank.
IEA	International Energy Agency.
IRA	Inflation Reduction Act.
IRENA	International Renewable Energy Agency.
JAC	Civil Aeronautics Board.
LACAC	Latin American Civil Aviation Commision.
LCA	Life-cycle assessment.
LCFC	Low Carbon Fuels Coalition.
LTAG	Long Term Aspirational Goal.
LTCS	Long-Term Climate Strategy.
MEN	Ministry of Energy.
MLIT	Ministry of Land, Infrastructure, Transport and Tourism of Japan.
MtJ	Methanol-to-Jet.
MTT	Ministry of Transport and Telecommunications.
PEN	National Energy Policy.
PtL	Power-to-liquid.
R&D+I	Research, Development and Innovation.
SAF	Sustainable Aviation Fuel.
UAE	United Arab Emirates.
UNFCCC	United Nations Framework Convention on Climate Change.
UK	United Kingdom.
US	United States.

Appendix
Background on the Public-Private SAF Roundtable

This appendix presents a summary of each of the five sessions of the Public-Private SAF Roundtable. The minutes, presentations, and recordings of the conference are available on the Clean Flight website.

Session 1: "Interest and challenges of airlines to implement the use of SAF"

Exhibitors: SKY Airline, LATAM, JetSMART, and Sustainability and Climate Change Agency (ASCC, by its acronym in Spanish). Foreign representatives also attended.

The following key points and proposals from the day were highlighted:

- Carry out a diagnosis of the raw materials required to produce SAF in Chile.
- Identify the impact of SAF on prices as a problem for business sustainability.
- Generate incentives for the use of SAF to reduce the price gap with fossil fuels.
- The airlines expressed their willingness to agree on goals and objectives, with the aim of guiding the industry in the use of SAF.
- Carry out a regulatory review and identification of gaps to implement new SAF policies, with regulatory coherence, both inside and outside Chile.
- Review the possibility of generating a Clean Production Agreement with the ASCC.
- Carry out benchmarking study on the experience of other countries.

Session 2: "Interest and challenges of importers, producers, refiners, and distributers/suppliers of SAF"

Exhibitors: IATA, ENAP, BioFuels (Brazil), Rendering, HIF Chile, and COPEC.

The following key points and proposals from the day were highlighted:

- Identify the raw materials available in Chile that could be used to produce SAF.
- Consider diversification in the use of raw materials and technologies, promoting innovation.
- Address the need to analyze the feasibility of the SAF market in Chile.
- Generate a regulatory framework that facilitates enabling market conditions which are adjusted to the reality of the country.
- Guarantee obtaining sufficient SAF to be able to meet the goals of the airline industry, with the availability of this fuel being one of the greatest challenges.
- Generate capital access mechanisms for new investments in SAF.
- Identify public policies that make SAF accessible by reducing its cost.

Session 3: "Interest and challenges of importers, producers, refiners and distributers/suppliers of SAF"

Exhibitors: Chilean Wood Corporation (Corporación Chilena de la Madera, CORMA), Honeywell, Neste, Universidad Católica de la Santísima Concepción, Linde, Empresa Nacional de Energía Enex S.A. and Air Liquide.

The following key points and proposals from the day were highlighted:

- There is sufficient installed research capacity at the laboratory level.
- Leveraging of investments is needed to accelerate the theoretical and academic aspect associated with the development of SAF.lea
- Create investment incentives to leverage the costs of technologies.
- Tax credits are an efficient way to promote the use of SAF, which is why it is proposed to study cases such as California in order to make progress on this topic.
- When designing policies that encourage SAF production, consider incentives for the production of biodiesel and other ethanol derivatives.
- Explore forest biomass as a raw material. This could be made available through forest and waste management plans of forestry companies.

Session 4: "Interest and challenges of regulation, certification, and research"

Exhibitors: Dirección General de Aeronáutica Civil, Pontificia Universidad Católica de Chile, Axens, SGS, and Universidad de Concepción.

The following key points and proposals from the day were highlighted:

- Consider the difficulty involved in modifying certain current contracts (e.g., the provision of fuel at airports), as they are long-term and cannot be easily altered. This could limit the use of SAF in future contracts.
- There are well-equipped Chilean universities that have made important advances in biofuels research, and that have the laboratories, equipment, and availability necessary to contribute in the field of SAF and pilot development.
- There is the possibility of installing new laboratories in Chile, which could encourage new regulations in relation to SAF.
- Green hydrogen requires further research to reduce production costs. Although blue and gray hydrogen are not considered sustainable options, there is existing installed capacity that must be used to advance relevant SAF studies.
- Forest biomass is viable as a raw material by integrating waste not currently used. This is possible through the creation of management plans for the native forest that allow for sustainable exploitation. Wood energy plantations must also be explored, considering sustainable exploitation.

Session 5: "International experiences with strategies and initiatives for production, distribution, and use of SAF"

Exhibitors: Civil Aviation Bureau of Japan's, Ministry of Land, Infrastructure, Transport and Tourism, U.S. Federal Aviation Administration, Low Carbon Fuels Coalition, European Union Aviation Safety Agency, Boeing, CAC Chemieanlagenbau and Chemnitz GmbH.

The following key points and proposals from the day were highlighted:

- Within the aviation decarbonization commitments in roadmaps, which take the IATA and ICAO recommendations as a guide, SAF are the leading option.

» It is necessary to evaluate the availability of raw materials in all countries promoting SAF development.

» A regulatory system capable of adapting to different SAF production scenarios is required.

» Roadmaps require public-private cooperation. The large investments necessary to generate the SAF market entail, in addition to state aid, active participation from the private sector.

» Financial aid from governments is a tool used to reduce the gap between the price of SAF and fossil fuel.

» Green credits or bonds are becoming increasingly relevant in the context of a SAF market, contributing to its competitiveness.

» Stacking is an option used in country policies. This implies being able to accumulate the benefits, incentives, measures, and/or policies in the production and use of SAF.

» The power-to-liquid process has great potential for decarbonizing the industry in the long term. The scaling of its production is projected from 2030 onward, when the maturity of its technology will allow for scaling.

Table A1. Links to documents generated in the public-private sustainable aviation fuel roundtables.

Session	Date	Record	Presentations	Transmission Link
Launch Roundtable	10 October 2022			
First SAF Roundtable	24 November 2022			
Second SAF Roundtable	12 December 2022			
Third SAF Roundtable	12 January 2023			
Fourth SAF Roundtable	16 March 2023			
Fifth SAF Roundtable	31 May 2023			

CHILE: SAF ROADMAP 2050

Sustainable Aviation Fuels

Ministerio de Energía
Gobierno de Chile

Ministerio de Transportes y Telecomunicaciones
Gobierno de Chile

Junta de Aeronáutica Civil
Ministerio de Transportes y Telecomunicaciones
Gobierno de Chile

Agencia de Sostenibilidad Energética

Vuelo limpio

IDB