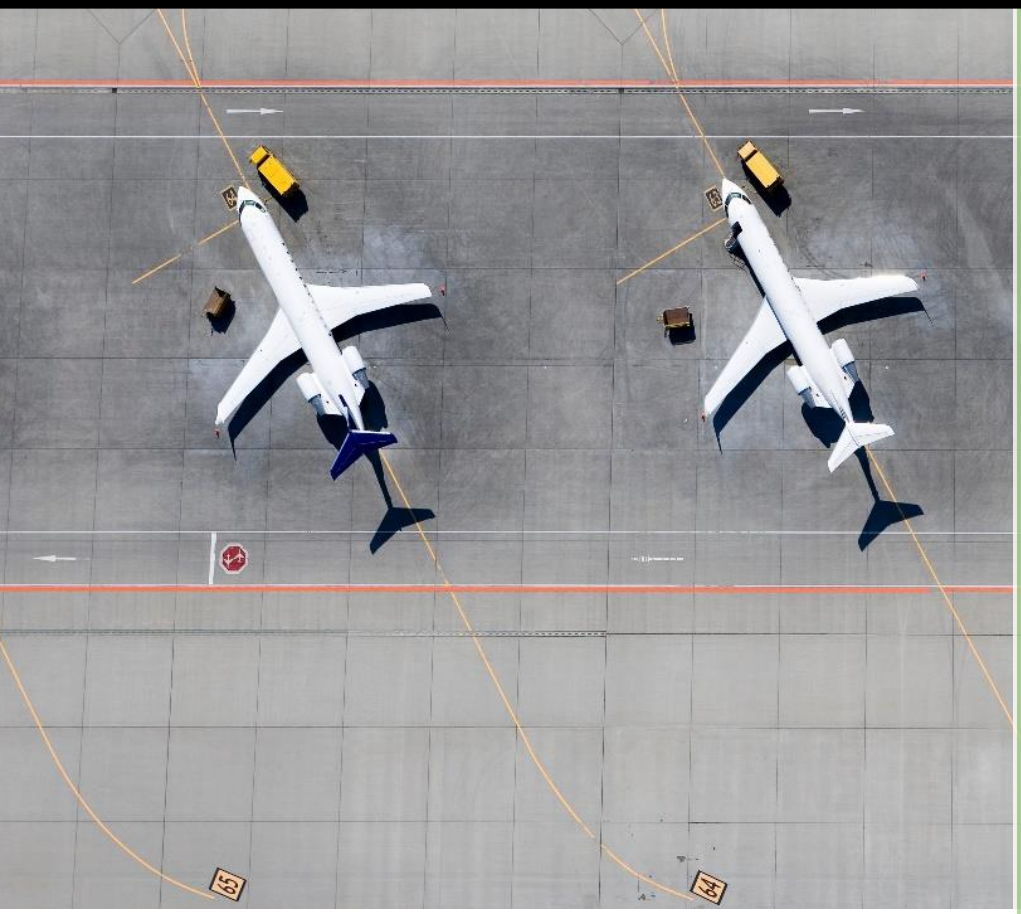
Sustainable Aviation Fuel Implementation Strategies for European Airports



By: Helena Michelle Rodriguez

Submitted to:

Dr. Ric Hoefnagels
Copernicus Institute of Sustainable Development
Utrecht University

Eoghan Davis
NACO

Final Master Thesis
GEO4-2321
Sustainable Development (MSc)
Utrecht University
30 ECTS

Date of submission: September 2023

Abstract

As the ambitious ReFuelEU mandate comes into force, with the goal of increasing the production and usage of Sustainable Aviation Fuels (SAF), the aviation sector has still to face uncertainties and questions about how this mandate will develop. The main obligations currently fall upon fuel suppliers and aircraft operators to meet certain SAF volumes; nevertheless, airports as the physical connecting point between them can still have a relevant role to play in the successful deployment and usage of SAF.

The mandate has not laid out clear strategies or guidelines for airports on what their role might be within the rollout of the mandate, aside from ensuring the fuel infrastructure is ready for the safe deployment of SAF. Airports and other stakeholders in the industry are left wondering and questioning the role of airports and which strategies should they implement to support the mandate. Incorporating background information, literature reviews, expert interviews, and stakeholder consultation notes, the research provides a guide to help airports understand their role and the steps needed to implement strategies in line with the ReFuelEU mandate.

This research investigates the role of airports within the fuel supply chain and their relationship not only to the mandate but to the deployment of SAF as an innovation; and what strategies airports can implement to support the SAF uptake by the industry. The research argues that airports can take on facilitator, enabler, lobbyist, and advocating roles, to support SAF deployment and the mandate.

There is a significant amount of information on strategies and best practices airports could implement to boost SAF uptake, nevertheless, many have not acted upon this, as the mandate and their context are not understood properly. Therefore, the guide provides five steps to help airports understand their own context and use it to their advantage to create strategic roadmaps that include SAF uptake strategies.

While the guide lays out the first steps to helping airports find their spot within the mandate, multi-stakeholder collaboration between airports and relevant players is necessary to meet the mandate's goals. Additionally, collaboration between other sectors/industries, and countries/regions is required to avoid conflicting competition for feedstock and fuel.

Keywords: SAF, ReFuelEU, role of airports, SAF implementation in airports, SAF uptake

Acknowledgments

This master's thesis is the last step to finally complete my master's education in Sustainable Development at Utrecht University, this achievement would not have been possible without the support of several people.

Foremost, I would like to express my deepest gratitude and acknowledgments to my thesis supervisor Ric Hoefnagels from Utrecht University, and Eoghan Davis from NACO for their constant advice, guidance, and support in every step of this process. I would like to extend these acknowledgments to NACO and my internship supervisors Vivek and Tom, for their support and feedback throughout my thesis. I would also like to thank all the interviewees who agreed to participate in this research, and I appreciate their time they gave to this; their input and information provided helped shape a crucial part of this thesis. Additionally, I want to thank my second reader, Wina Crijns-Graus whose feedback and questions in the proposal provided me clarity and direction early in my thesis.

I am also deeply grateful to my family in Mexico and Hungary, particularly, my parents Krisztina and Sergio, and my sister Uma for constantly believing in me and providing me unconditional love and support despite the distance.

Additionally, this would not have been possible without the support of all my friends, especially Betty, Karen, Thanos, and Jules for their consistent motivation, emotional support, and advice throughout my master's and this thesis; Lastly, I want to thank my boyfriend Arthur who has cheered me on, encouraged and supported me.

TO MY FAMILY AND FRIENDS

Helena M. Rodríguez
September 2023

Table of Contents

List of Figures

List of Tables

Abbreviations

ACI – Airports Council International
ATAG – Air Transport Action Group
ASTM – American Society for Testing and Materials
CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation
EASA – European Union Aviation Safety Agency
ETS – Emissions Trading Scheme
EU – European Union
FT – Fischer-Tropsch
HEFA – Hydroprocessed Esters and Fatty Acids
IATA – International Air Transport Association
ICAO – International Civil Aviation Organization
LTAG – Long-Term Global Aspirational Goal
PtL – Power to Liquid
RED II – Renewable Energy Directive II
SAF – Sustainable Aviation Fuels
SAF Congress – Sustainable Aviation Futures Congress

1. Introduction

Aviation has increasingly become an important transportation mode for people and goods; it plays a vital role in today's economy and socio-economic development (ICAO, n.d.-a). In the European Union (EU) the aviation sector provides more than 13.5 million jobs, and it contributes 4.4% to the European GDP as of 2018 (ACI EUROPE, n.d.). Regardless of the benefits that air transport provides, the aviation sector is responsible for 2.5% of the global CO_2 emissions, and 1.9% of global warming impact (non-CO_2 emissions) (Ritchie, 2020). Despite the setback caused by COVID-19 between 2019-2021, the aviation sector is on track to recover to the projected annual growth rate of 5% (IATA, 2022a; Tidey & Wright, 2023).

As climate change and global warming become more concerning, international agreements and pledges have been made, such as the Paris Agreement with the aims to limit temperature increase by 1.5°C above pre-industrial levels (UNFCCC, 2015). Nevertheless, the agreement does not explicitly include the emissions from international aviation and shipping, this undermines the goals of the agreement to limit the temperature increase and reduction of emissions(Transport & Environment, 2016). The compounded annual growth rate of 3.1% in aviation from 2019 till 2050 including COVID-19 pandemic effects, without any improvements to the industry this means 2.0 Gigatonnes (GT) of CO_2 emissions will be generated by 2050 (ATAG, 2021).Regardless of the aviation industry not being considered in such agreements, the industry has shown some concern about the growth of emissions. This has led the aviation industry and other international organizations to act, the International Civil Aviation Organization (ICAO) has since been working on establishing goals aligning with those set in Paris (Graver et al., 2022). There is an increasing debate and discussion on the various ways to make the aviation sector greener, one of the main targets in the industry is to achieve decarbonization by 2050(Schafer et al., 2022).

In 2016, ICAO adopted a Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), demonstrating global commitment to the decarbonization of the sector (Schafer et al., 2022).The goal of CORSIA is to mitigate CO_2 emissions from international aviation starting from 2021, subjecting international airlines to offsetting obligations(IATA, 2023a). Nevertheless, emission trading schemes such as CORSIA have been deemed not enough to reach decarbonization targets in the aviation industry(Schafer et al., 2022). To fill this gap and support the 2015 Paris Agreement targets, ICAO adopted a long-term aspirational goal (LTAG) to reach net-zero by 2050 (ICAO, n.d.-b). There are multiple approaches that can be taken to reduce emissions from international aviation, however, technical analyses performed by ICAO show that Sustainable Aviation Fuels (SAF) have the most potential to reduce CO_2 emissions from the aviation industry globally (ICAO, 2022a).

ICAO defines SAF as: “Renewable or waste-derived aviation fuels that meet sustainability criteria”(ICAO, n.d.-b). There are several pathways to produce SAF by using different types of feedstocks (sources from which the fuel can be produced), many of which have been certified and qualify to be used in the present aircrafts and infrastructure (EASA, n.d.). Due to its high emission reduction potential, CORSIA and LTAG both have included SAF in their methodologies and reports respectively. This has been additionally supported by other organizations in the aviation industry, outlining the importance of SAF to achieve decarbonization from the aviation sector (ATAG, 2021; Destination 2050, n.d.; EASA, 2021; EUROCONTROL, 2022; NLR & Destination 2050, 2021).

International agreements and commitments from organizations in the aviation sector have shown progress, nevertheless they lack clear strategies and specific goals to meet ambitions such as decarbonization and net-zero by 2050. Nevertheless, the EU has become a frontrunner in ensuring such goals are implemented, by developing more specific and clear strategies for all EU members (European Parliament, 2022b). As of 2021, the EU has set in motion the European Green Deal, presenting a comprehensive policy framework strategy to achieve climate neutrality by 2050 (European Commission, n.d.). To achieve these goals the EU must reduce transport emissions by 90% by 2050 in comparison to those of 1990, therefore the aviation sector will have to contribute to this reduction set (European Commission, n.d.). The EU has since proposed the introduction of the ReFuelEU Aviation mandate, with the goal of increasing the production and usage of SAF in the EU (European Parliament, 2022b). The new set of rules aim to help decarbonize the sector, by primarily putting pressure on fuel suppliers and aircraft operators to ensure a certain amount SAF is deployed (European Commission, 2023b). The mandate has already released a set of rules which indicates what will be required by the main stakeholders, this includes aircraft operations, aviation fuel suppliers and airports.

1.1. Problem Definition and Aim

As stated by the European Commission, the new ReFuelEU mandate will require stakeholders in the aviation industry to take certain actions, this includes airports, who have been required to ensure the infrastructure for fuelling aircrafts is ready for safe SAF distribution (European Commission, 2023b). Nevertheless, the mandate does not mention the specific changes or requirements the airports specifically need to comply with regarding infrastructure or any additional measures. This has left airports with further questions and concerns on how they will be affected by the mandate and what role they will be playing or should be playing in the uptake of SAF and the coming mandate.

Airports could play a significant role in the growth and diffusion of SAF, they could be considered the connecting point between fuel suppliers, the airlines, and even governmental bodies(RBS, 2022). They could have certain power to facilitate the transaction between them and provide the infrastructure that benefits all parties. Several prominent airports around Europe have formed different consortiums such as STARGATE, TULIPS, OLGA, and ALIGHT. These consortiums receive funding from the EU as part of the European Green Deal and Horizon 2020; the aim of these consortiums and projects is to find sustainable aviation solutions, develop innovations to aid in the decarbonization of the industry and knowledge sharing between other consortiums/projects(Viinikainen, 2022).

The proposal for the ReFuelEU mandate on SAF implementation has been laid out, however, there is no clear advice or strategy in place that indicates how these goals are to be achieved or replicated specifically by airports (van Dyk, 2021). The consortiums are still awaiting on what this means for them and what are the next steps to be implemented considering the mandate. Therefore, the creation of a guide could aid these airports to further promote the diffusion and uptake of SAF to achieve the set of rules outlined by the ReFuelEU mandate. Airports are under constant public scrutiny and pressure to show accountability and transparency when it comes to sustainability actions(Opare Mintah, 2023). The introduction of the mandate puts an additional pressure on airports, nevertheless the implementation of SAF could not only benefit airlines and fuel suppliers in meeting environmental targets, but airports can also benefit from its implementation(RBS, 2022). The usage of SAF, along with airports being involved in its uptake, can lower their Scope 3 emissions (value chain emissions); it can

help improve the air quality surrounding the airports, reducing NOx, particulate matter, and other emissions(RBS, 2022). Lastly, involvement in SAF projects and uptake can aid in meeting their sustainability targets within the ACI Airport schemes (NESTE, n.d.).

The aim of this thesis is to provide a guide for airports on the implementation of SAF strategies, in line with the ReFuelEU mandate. This is done based on information from the background information, the literature reviews, interviews, and attendance at the Sustainable Aviation Futures Congress (SAF Congress) on the topic. The guide's goal is to showcase how airports could work toward reaching the set goals by the mandate, what role they could be playing, aid in the decarbonization of the aviation sector by 2050 and facilitate the growth of SAF. Furthermore, this research helps gather relevant information on SAF development, current best practices that are already being implemented, challenges/barriers, concerns from stakeholders, and general advice for airports on the topic.

1.2. Research Question

Considering the information provided and the problem definition stated, the following research question has been drafted:

What strategies can European airports implement to aid in the achievement of the ReFuelEU mandate up to 2050?

Several sub-research questions have been formulated that are crucial to this research and are needed to answer the main research question. These questions primarily aim to shed light on supply chain matters and how airports should be involved in it, the importance of them as stakeholder in the further deployment of SAF and what are relevant lessons learned that can be further replicated.

Sub-research Questions:

1) What role are airports playing and what role they should be playing in relation to SAF uptake and ReFuelEU?
2) What is the impact on airport operations and physical infrastructure for SAF implementation in accordance with the mandate?
3) What are the benefits and challenges of being a front-runner versus a late-adapter airport?
4) What are the expected market trends of SAF deployment and what are the main risks, opportunities, and barriers of SAF implementation that airports will face?
5) What are current best practices at other airports regarding today's SAF implementation?

1.3. Scope

This research will solely focus on airports and flights taking place within the European Union. The choice to focus on the ReFuelEU mandate is due to the geographical proximity and relative novelty of the mandate; additionally due to NACO's interests on the topic, their contacts in the industry and clients.

This research will not focus on specific aspects and technicalities of SAF, from feedstocks and the conversion methods of SAF, it will only touch upon them generally for context

purposes. Furthermore, the research will not consider how the demand will be met with the feedstock, it will be focused on the airports' perspective and the role they play between the supplier and the airline. This is primarily due to time constraints and the interest of the company specifically the airports' role. Moreover, an in-depth roadmap will not be provided, only inputs and advice that can be used to generate custom-made roadmaps for specific airports.

In-depth financial models and aspects won't be considered, funding and importance of such aspects will be touched upon, however, the amount of time available will not be enough to produce in-depth results for these topics.

The research will not cover details on alternative fuels such as hydrogen and electric, and their specific future impact to airports.

2. Background

The following chapter explains key concepts that were crucial for the research, to gain a high-level understanding on the aviation fuel landscape and how SAF comes into play in the industry. It was important to first understand the general background on the industry, the ReFuelEU mandate and SAF diffusion, to gain a deeper understanding on the topic and subsequently develop the methodologies used in this research. First, the jet fuel & SAF supply chain are roughly explained; then the concept of the decarbonization of the aviation is described as an introduction to the usage of SAF and how it plays a role in the decarbonization of the industry. This will lead to a deeper explanation into SAF, conversion processes, certain feedstock types and other concepts that relate to the implementation of SAF. Following this, the ReFuelEU mandate is briefly explained, highlighting the relevant information in relation to airports, additionally the ongoing EU airport consortiums will be summarized in this section. Lastly, the diffusion innovation theory, key terminology on this, and adaptor categories of innovation are introduced. These definitions and the theory were relevant for the analysis of the results of this research, defining the role of the airport and observing what will be the benefits and challenges of front runner airports versus those that wait for the mandate; additionally, this section also gives a summary of the history of SAF development, giving an overview of how SAF has been diffused overtime.

2.1. Understanding the Jet fuel & SAF supply chain

It is important to understand how the current jet fuel supply chain works to see how it interacts with the SAF supply chain and to visualize if the supply chain needs to be changed or modified to meet the ReFuelEU mandate. This will allow us to comprehend if airports could fit into the SAF supply chain or what their role might be in the future of SAF diffusion and uptake. The supply chain for both conventional jet fuel and SAF are complex, in this section a brief explanation will be given to provide a general overview on how these supply chains work on average. It is important to note that the supply chains differ per region, country and even between fuel suppliers, the following information is a generalization and simplification on how the supply chains are set up on average.

The Figure 1: Jet Fuel Supply Chain (Airlines for America, 2018, p.6) below from Airlines for America (2018) provides a general visual summary on how the supply chain for conventional jet fuel is set up. Usually this is considered as part of the upstream supply chain, which is generally taken care of the fuel producer. In the case of jet fuels, airports and airlines are not involved in the upstream part of the supply chain, generally airlines have contracts with fuel suppliers on the quantity required and the location that it will be needed (Airlines for America, 2018). Airlines buy the fuel directly from the fuel supply at the beginning ot the refining stage (reference). The Figure 1: Jet Fuel Supply Chain (Airlines for America, 2018, p.6) below shows what occurs after the drilled fossil fuel enters a refinery, in which different oil products are refined, such as kerosene; nevertheless, kerosene must be tested and certified as Jet-A1 fuel to meet safety standards. Once the refining and testing process is covered, usually the product is moved by a pipeline to a third-party terminal, from here it is distributed to different segregated off-airport terminals, afterwards it is transported to off-airport storage tanks. These off-airport storage tanks provide temporary storage for the fuel until it is further transported by truck (usually to smaller airports) or a local pipeline to the on-airport storage tanks. To refuel a plane, this can be done by refueling trucks at the airport (usually provided by fuel suppliers), or it can

be moved to the airport's hydrant system, both are in charge to refuel the airplane before take-off.

Figure 1: Jet Fuel Supply Chain (Airlines for America, 2018, p.6)

The supply chain for SAF can be slightly more complex since an additional fuel type has to be blended with conventional jet fuel. The Figure 2: SAF Supply Chain (Martinez-Valencia et al., 2021, p..4), describes a simplified version on how the SAF supply chain works taken from (Martinez-Valencia et al., 2021). SAF starts with the collection of the feedstock required to produce said SAF, the collection is also taken care of the fuel supplier/provider of SAF. The collection of the feedstock could be taken care by a second party, and the fuel providers buy the collected feedstock; then the feedstock is the pre-processed, converted into SAF, which could be also done by a specialized SAF or biofuel supplier. The pre-processed SAF is then blended in with conventional kerosene, the blending ratio of SAF depends on the chosen conversion process and the approved ratio by ASTM (Martinez-Valencia et al., 2021). After the blend-in process with kerosene, the fuel it is carefully tested, certified for safety and other technical aspects are checked. Once this is done the fuel is similarly distributed as the jet A1 fuel to airlines, which was described above. There are specialized SAF fuel producers which partner with bigger oil producers for the blend-in of SAF with kerosene. They take care of the certifications and paper works needed for the assurance of SAF's safety.

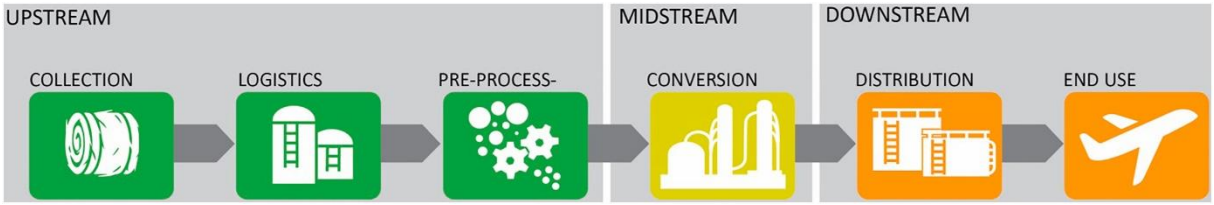


Figure 2: SAF Supply Chain (Martinez-Valencia et al., 2021, p..4)

2.2. Decarbonization in the Aviation Industry

As mentioned in the introduction, the aviation sector is responsible for a significant amount of emissions, as the demand for air transport and travel grows, achieving decarbonization in the aviation sector is essential to meet the international climate goals (Ellerbeck, 2022; ICAO, 2022b). As of 2019 the aviation industry consumed 363 million litres of kerosene, equivalent to 914 million tons of CO_2 emissions(ATAG, 2020) . This does not consider non-CO2 emissions and global warming impacts, which cause up to four times the effects from that of CO2 emissions (López de la Osa, 2022).

The main goal of decarbonization of the aviation sector is to move away from the usage of fossil fuels and replace these by other innovations and technologies (Institut Montaigne, 2022). According to the Waypoint 2050 report by ATAG, 2021, there are a set of measures than can be applied by the industry to help fight climate change and reach decarbonization. These include reviewing traffic forecasts, technological innovations, operations and infrastructural improvements, deployment of SAF and carbon offsets (ATAG, 2021). The Table 1 below gives a brief example on each of these measures and what it entails, the information from the table has been adapted from the Waypoint 2050 report (ATAG, 2021).

Table 1: Adapted from Waypoint 2050 decarbonization measures (ATAG, 2021, p.4)

Measure	Definition/Example
Traffic Forecasts	Due to the continues forecasted growth of population and economy, the aviation sector is expected to further grow. With the growing concern on climate change it is suggested to further investigate slowing down the growth or degrowth of the industry
Technological Innovations	Technology development has improved fuel efficiency. In the next 30 to 50 years improvements in efficiency and technologies will have a big impact on the industry. It is expected that electric, hybrid, and hydrogen aircraft will play a role in short and medium-haul flights. For long-haul flights, a transition to sustainable and low-carbon resources.
Operational and Infrastructural improvements	Airports, airlines, and air traffic management should work together to implement measures to reduce CO2 emissions from operations. This includes electrification of ground operations, implementation of renewable resources, airport connectivity and efficient air traffic control.

SAF	The most relevant opportunity for the industry to reach 2050 goals is the usage and deployment of SAF. The industry will probably require 330-445 million tonnes of SAF per year to meet the demand by 2050. To meet this collaboration between stakeholders is needed, policy must be in place and the development of technology is needed.
Carbon Offsets	In the short-term the aviation sector will need to rely on offsets. This is a short-term solution until more sustainable and alternative energy options are available in the long run.

The Waypoint 2050 report has also developed 3 scenarios on the development of the industry to reach net zero by 2050. The baseline scenario can be seen in the Figure 3 below, which displays the continuation of current trends in operational improvements and technological developments, a compounded annual growth of 3.1% in air traffic from 2019 till 2050, SAF investments will follow the current curve with 100% emission reduction factor by 2050, lastly offsets will play the most important role to reach the 2050 goals in the base scenario. (ATAG, 2021).The other scenarios presented in Waypoint 2050 show different paths than the industry can take to meet net-zero carbon emissions by 2050. The first scenario focuses on pushing technology and operations, the second scenario is aggressive SAF deployment, the last and third scenario is based on aspirational and aggressive technology perspective (ATAG, 2021). In all these scenarios, SAF has the biggest emission reduction contribution, these can be viewed in detail in the Waypoint report (ATAG, 2021) .

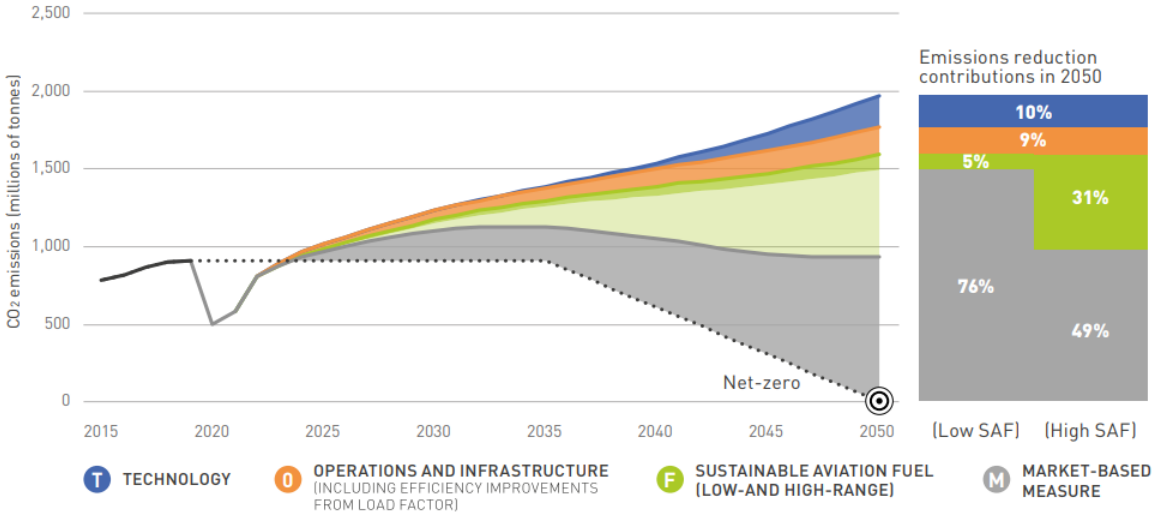


Figure 3: Waypoint 2050 baseline scenario (ATAG, 2021, p.23)

The air transport industry is one of the most challenging ones to be able to reach decarbonization, there are multiple factors that play a role for the industry to reach net zero (EUROCONTROL, 2019). This is mainly due to the complexities involved in aviation, there are various systems involved and interconnections, such as the infrastructure of aviation (airports, aircraft), the specific safety and regulation standards, telecommunications systems, and much more (EUROCONTROL, 2023).Moreover, the industry has multiple stakeholders involved, all with different goals and priorities to be met. This further complicated the industry; it is challenging to manage all the expectations of stakeholders to meet such decarbonization goals. For airports specifically, research has shown the need to emphasize stakeholder

involvement, and the need to include systematic assessment (considering different emissions and regional differences) when looking at airport sustainability and decarbonization actions(Greer et al., 2020).

The aviation sector's decarbonization has a long way to go and many obstacles to tackle. The industry is considered a long-term industry, which involves the return on investment being measured decades in advance, which makes it even more challenging to decarbonize quickly (EUROCONTROL, 2019). There is a growing interest in different innovations within the industry includes alternative fuels and technologies to power planes, such as SAF, hydrogen fuel, and electric power airplanes (Su-ungkavatin et al., 2023). However, many of these options are still in development and require even more complex changes to fully adapt them and make them competitive against conventional jet fuel (IATA, 2021a; Su-ungkavatin et al., 2023).

A group of European airlines, airports aerospace manufacturers, and air navigation service providers have come together to form Destination 2050; with the goal to lay out long-term visions and solutions to achieve net zero CO_2 from all flights departing from the EU, UK and EFTA (European Free Trade Association) (Destination 2050, n.d.). They have created a report alongside Royal Netherlands Aerospace Centre (NLR) to layout a decarbonization roadmap, this roadmap can be seen in Figure 4: Destination 2050 Decarbonization Roadmap (Destination 2050, 2021); the roadmap shows that SAF will play the most important role in decarbonizing the European aviation industry, 34% of decarbonization targets will be met by SAF (NLR & Destination 2050, 2021).

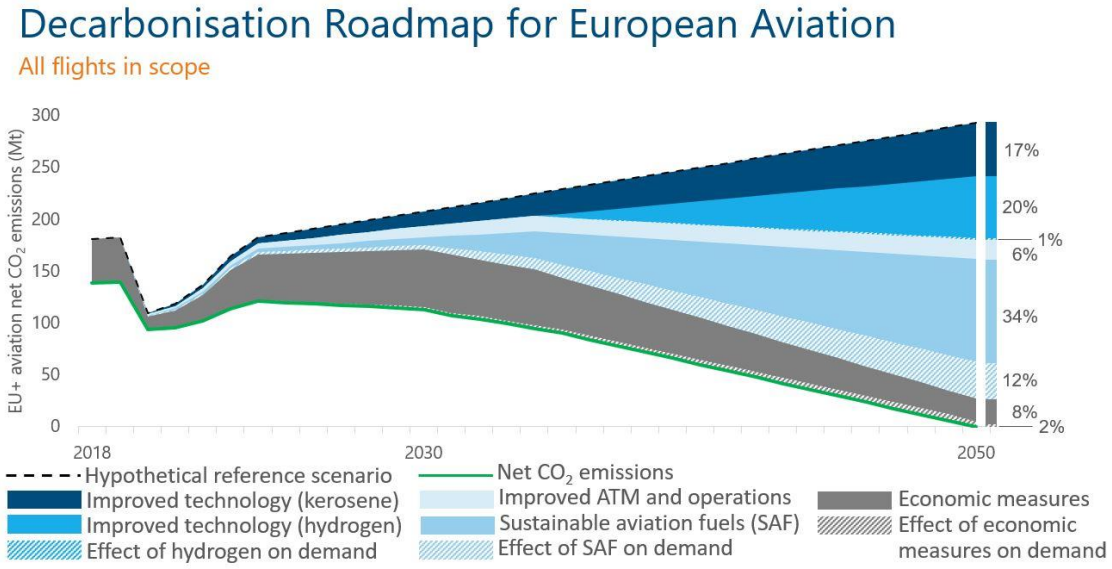


Figure 4: Destination 2050 Decarbonization Roadmap (Destination 2050, 2021)

The figures (Figure 5 and Figure 6) showcase ICAO's efforts and targets to decarbonize the industry. In Figure 5, the 4 pillars set by ICAO can be seen, these are actions and mechanisms that can be already implemented to reach the decarbonization goals. Figure 6 shows a projection of the decarbonization of the industry and its impact on real carbon neutrality by 2050; additionally, it shows that biofuels and additional technologies will have the most impact in the future and long-term to achieve the targets.

Figure 5: ICAO Decarbonization Pillars (EUROCONTROL, 2019)

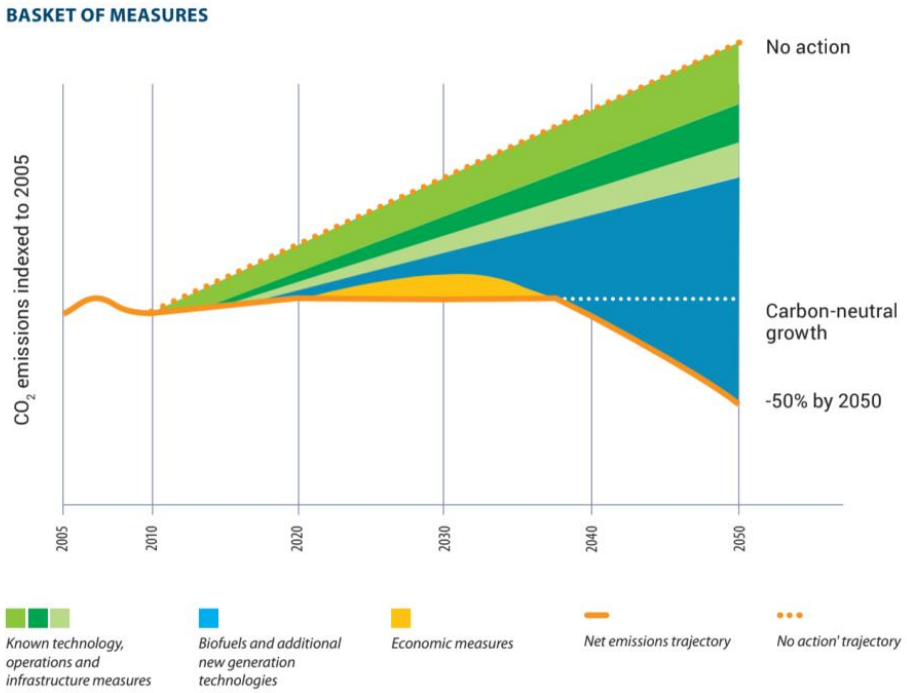


Figure 6: ICAO Decarbonization Measures (EUROCONTROL, 2019)

Considering the current situation, the most immediate solution that could accelerate the decarbonization of the industry apart from offsetting mechanisms is the deployment and implementation of SAF(EASA, 2022a; Ellerbeck, 2022; IATA, 2021b). It could be a driving factor for airlines to mitigate their emissions directly at source (Faber et al., 2022; IATA, 2021b; Transport & Environment, 2022). Airports, as part of the industry and at the centre of it are committed to helping achieve the targets on decarbonization(Borodin & Barbarà, 2023); many of the measures described in the table above require the collaboration of airports for them to be successfully implemented. Encouraging the usage of SAF can contribute to the airports

voluntary decarbonization goals, by allocating the reductions to the airports' Scope 3 emissions(RBS, 2022).

2.2.1. SAF: Drop-in Fuel

As mentioned in the introduction, SAF refers to fuels which derive from non-fossil sources, more specifically biological feedstock. These fuels aim to close the carbon cycle through the cultivation and production process, this results in life-cycle emissions reduction to those compared to traditional jet fuel(IATA, n.d.). The term "SAF" is used by the aviation industry, however, the broader SAF is a more specific term to refer to biofuels, naturally SAF must meet separate certifications and safety standards(ATAG, 2017). Current technology allows SAF to be produced by non-biological sources as well; the final product by either biological or non-biological sources is blended with conventional kerosene, creating SAF. The SAF is then tested and certified to classify as 'Jet A-1' fuel and without any additional modifications it can be used in the aircrafts (ATAG, 2017).

SAF has similar chemical and physical characteristics to those of conventional jet fuel, which as previously stated, it can be safely blended with conventional jet fuel at different degrees; this fuel can be used in existing infrastructure and aircrafts, these types of fuels are defined as 'drop-in fuels'(IATA, 2023c). For SAF to be considered sustainable, several sustainability criteria must be met, to prove it reduces emissions throughout the life cycle to those of conventional jet-fuel (IATA, 2023c). Currently the maximum allowed blend by ASTM is 50%, this is mainly due to the aromatics needed for seal compatibility in the aircraft; this could change in the future when aircrafts are able to fly on 100% SAF(van Dyk, 2022).

There are many diverse types of feedstocks that can be used to produce SAF, such as municipal solid waste, cellulosic waste, cooking oil, crop, and plants (camelia, algae) and power and hydrogen (used in Power-to-Liquid process) (EASA, n.d.). The Table 2 below, adapted from Soone (2020) and EASA (2022b) show current certified and approved conversion methods for SAF, each with its maximum blending potential and the feedstocks it can be produced from. Each batch of SAF created must be tested and certified in a laboratory before being used in aircraft.

Table 2: SAF Conversion Methods (Adapted from Soone, 2020. & EASA, 2022.)

Technology	**Maximum Blend in Final Product (%v/v)**	**Feedstocks**
FT-SPK & FT-SKA	50	Waste(e.g Municipal solid waste), sawdust, energy crops and lignocellulosic biomass.
HEFA-SPK	50	Lipid feedstocks like vegetable oils: used cooking oil, palm oil, camelia oil, jatropha oil, tallow, and animal fat.
HH-SIP or HC-HEFA	10	Oils produced from algae.

HFS-SIP (hydroprocessing of fermented sugars – synthetic iso-paraffinic kerosene)	10	Modified yeast, lignocellulosic sugars, and conventional sugars.
ATJ-SPK (Isobutanol and Ethanol)	50	Sugar, starch crops and lignocellulosic biomass
Catalytic Hydrothermolysis Jet fuel (CHJ)	50	Vegetable and animal fat (Triglycerides: soybean oil, jatropha oil,

Other options include Power to Liquid (PtL) using the FT conversion technology. PtL uses renewable electricity, water, and carbon dioxide to produce green hydrogen, and with FT synthesis the product can be mixed with kerosine. Nevertheless, PtL still remains very costly compared to the other processes for the amount that is produced, still PtL is expected to be used at a larger scale between 2025 and 2030(Airbus, 2021).

As briefly stated above non-drop-in SAF or 100% SAF, as well as other fuels (hydrogen and electric) are currently not compatible with the existing aircraft fleet, for this to be possible it would require a new fleet, certifications, and significant infrastructural changes (EASA, 2022b). The industry is currently still performing research and tests on this, expecting some aircraft engines to be able to fly with 100% SAF by 2030 (EASA, 2022b).

2.2.2. Book & Claim and Mass Balance

Many end-users such as airlines, airports, or buyers are increasingly demanding the usage of SAF, however, SAF is not always available on demand in their existing supply chain. SAF is currently only being produced in a handful of countries and is available at even fewer airports, this means that the fuel is not physically available for customers worldwide who want to reduce their air travel emissions (RSB, 2023). This is where the book & claim solution comes in, it enables airlines to purchase SAF without having the necessity of being connected physically to the supply site, it technically purchases SAF for another airline and receives the benefits from the emission reduction from that flight flying on SAF. Figure 7: Book & Claim System (RSB, 2023) depicts how the system function, by allowing a flight with proximity to SAF to fly on such fuel while another airline claims the benefits of it. Such a mechanism enables suppliers to reach more physical customers and promotes the usage of SAF worldwide, while the customer is not directly flying with SAF the power of purchase shows market demand and supports the continues supply of SAF (RSB, 2023).

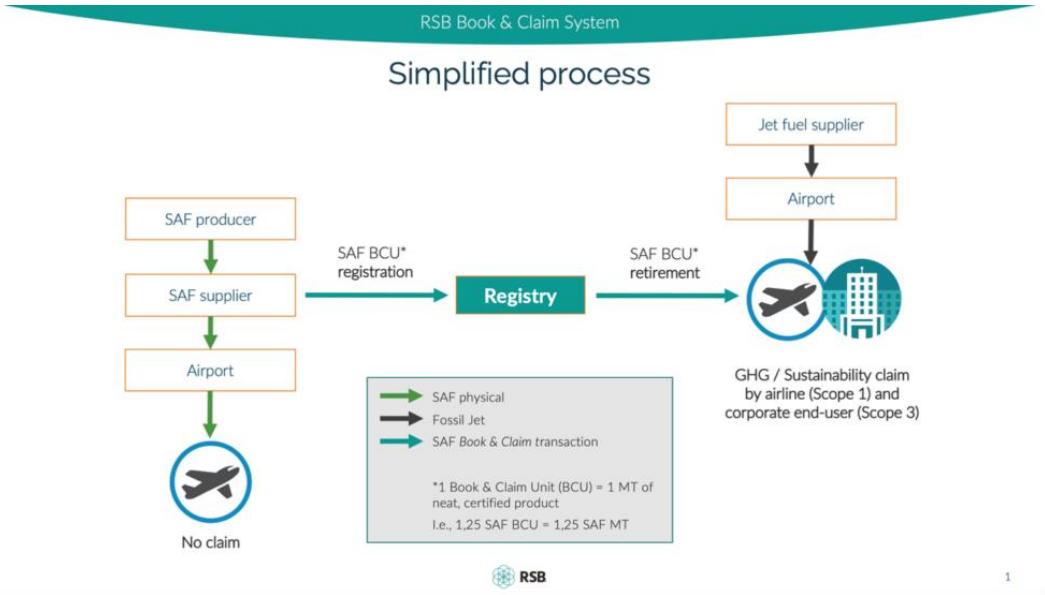


Figure 7: Book & Claim System (RSB, 2023)

The Mass Balance approach works differently than the book & claim, SAF is mixed with traditional jet fuel and is delivered to a selected airport hub where the flight will directly use it (Air bp, 2022). The SAF fuel is injected into the main fuel system at the airport, such as the hydrant system and is distributed among the aircrafts, the Figure 8: Mass Balance Approach (ISCC, n.d.) below shows how it works in principle; only the airline who initially purchased the SAF injected can claim the reduction from it, even if they do not physically have the fuel mix themselves on their wing(Pardoe, 2022). For mass balancing to work it is crucial to have traceability of the fuel throughout the entire supply chain, from the moment it is purchased, up until it is delivered and mixed into the airports fuel system(Pardoe, 2022) .

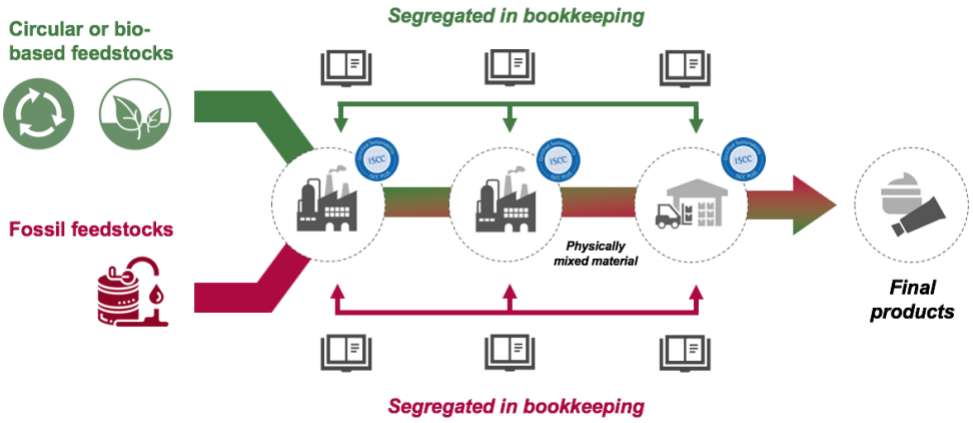


Figure 8: Mass Balance Approach (ISCC, n.d.)

Both these mechanisms are crucial for the diffusion and upscaling of SAF, nevertheless, the European Commission has not officially confirmed how these mechanisms will play a role in the ReFuelEU mandate. In the proposal published in July 2022 by the European Parliament, several amendments suggest the possibility of using the book & claim system, to ensure flexibility along the SAF supply chain(IATA, 2023d) . The Emissions Trading Scheme (ETS)

and CORSIA frameworks currently do not allow these mechanisms to take place, however, currently there is much discussion on how these systems can be included (Pardoe, 2022). These mechanisms are still under scrutiny and discussion, for them to be implemented they need to have a robust framework backing them up, protecting them against fraud and double counting (Pardoe, 2022). The Commission has already stated that SAF supply will not be fairly distributed across Europe, making it even more essential to have proper book & claim and, mass balance mechanism in place before the mandate kicks in(IATA, 2023d).

2.3. ReFuel EU

As part of the European Green Deal, the European Commission unveiled the "Fit For 55" package which contains proposals that aim to cut emissions from the transport sector(European Commission, 2023b). A key proposal for the aviation industry includes the ambition to increase the production and usage of SAF, this proposal has been denominated as the ReFuel EU Aviation initiative (European Parliament, 2022a). This proposed mandate goes in accordance with the Renewable Energy Directive (RED II), the Emissions Trading Scheme (ETS) and multiple other European regulations that are already in place, nevertheless these two regulations will not be explained in detail in this research(European Commission, 2021a).

The main goal of this proposal is to put forward an obligation onto fuel suppliers to distributer a certain amount of SAF when supplying any other type of fuel to EU airports (European Parliament, 2022a). This is to further boost the uptake of SAF by airlines and therefore reducing emissions from the industry. The proposal further aims to level the playing field for airports and airlines, avoiding extra emissions due to the additional weight from the excess of fuel that the aircraft is carrying(European Parliament, 2022a). The primary target of this initiative is to reduce greenhouse gas (GHG) emissions by minimum 55% compared to the levels of 1990 (Soone, 2022).

The "Fit for 55" package proposes a gradual uptake of SAF usage in air transport starting from 2025 until 2050, the bill aims to directly implicate aviation fuel suppliers and aircraft operators(Council of the EU, 2022) . Fuel suppliers will be required to supply the minimum share (Table 3:Shares of SAF uptake (Adapted from European Parliament, 2023)) of SAF at EU airports(European Parliament, 2023); the current scope of the mandate involves airports that host more than 1 million passengers or airports where freight traffic is more than 100,000 tonnes a year(Soone, 2023). Aircraft operators will be obliged to uplift SAF blended fuel at EU airports with only the required fuel, the commission proposed that this will affect aircraft operators with 729 flights per year(Soone, 2023) ; the Council and the Parliament have proposed alternatives to this, the Council aiming to include aircraft operators with at least 500 flights per year, and the Parliament proposing to include those operators with 52 or more flights per year.

The targeted growth mandated by the EU mandate can be seen in the adapted Table 3 the table displays the values the EU commission published as of April 2023(European Parliament, 2023). To meet the climate targets from the EU, a minimum of 70% of the aviation fuel used in flights departing from EU airports must be SAF fuelled by 2050, this will include alternative technologies (synthetic fuels or e-fuels) that hopefully will become commercial to meet set targets (EASA, 2021; European Parliament, 2023). This will impact airlines not only from the EU but also, non-EU carriers that want to operate in EU airports.

Table 3:Shares of SAF uptake (Adapted from European Parliament, 2023)

	2025	2030	2035	2040	2045	2050
Percentage of SAF used in air transport:	2%	6%	20%	34%	42%	70%
Of which: sub-mandate Synthetic fuels (or e-fuels):	-	1.2%	5%	8%*	11%*	34%

*Amount not confirmed by the Parliament

As briefly mentioned in the introduction, the mandate has indicated that airports should ensure the infrastructure is ready to uptake SAF safely(Soone, 2023). Additionally, the ReFuelEU mandate and Green Deal will require airports to provide electricity to stationary aircrafts at all gates by 2025, and by 2030 electricity should be provided to all remote stands as well (European Commission, 2023).

The mandate also addresses tankering practices, in which aircrafts deliberately carry extra fuel to evade having to refuel with more expensive fuels such as SAF (Mitchell, 2023 . The flights departing from European airports functioning on conventional jetA1 fuel will be restricted to only refuelling with only the necessary amount for the flights (Mitchell, 2023).Additionally, the commission aim to level the playing field for fuel producers with the introduction of the mandate, this will further reduce the dependence on imported energy and create new jobs (Mitchell, 2023). Nevertheless, the mandate has yet to be approved by the European Parliament and the Council of the EU, to finally adopt the mandate across member states (Mitchell, 2023) .

The penalties for non-compliance will be finalized by 31st of December of this year, currently the fines stand for both fuel suppliers and aircraft operators under the scope of the mandate that do not fulfil the obligations (European Commission, 2021b). According to the proposal, aircraft operators that do not comply will be fined twice the calculated value depending on the aviation fuel prices and the quantity not tankered(European Commission, 2021b). Aviation fuel suppliers that do not comply will be fined twice the fixed value considering the price differences of the fuels (conventional and SAF) and the non-compliant quantities of the fuel. Furthermore, fuel suppliers not complying with the synthetic fuel mandates will be further fined at least twice the calculated value of the difference between the synthetic fuel and the conventional fuel price, and the non-compliant quantity(European Commission, 2021b).

The Commission has proposed to transfer the fines collected to InvestEU Green Transition Investment Facility, to further stimulate the research and innovation on SAF and its uptake in the industry(Soone, 2023).

2.3.1. EU Consortiums

The European Union has helped set up multiple consortium projects around member states as part of their Horizon 2020 program, to further contribute to making the EU more sustainable and achieve net zero. These consortium projects have been given funding by the EU to develop, research, collaborate and implement solutions in the aviation industry to move towards the EU goal of making airports and aviation greener.

Airports around the EU are in the lead of these consortiums, in which constant collaboration occurs between multiple airports and even between the consortiums themselves for knowledge sharing. There are four main consortiums which involve most of the biggest airports in the EU,

these are shortly described below. It is recommended to access each consortiums specific website for detailed explanations on their activities and goals.

TULIPS – This consortium started in January 2022, aims to accelerate innovation and sustainable aviation technologies that can contribute to the decarbonization of the aviation industry and zero waste airport goals. The Amsterdam Schiphol Airport as frontrunner, is being used for demonstrations arising from the consortium (TULIPS, n.d.).

OLGA – As of October 2021 with Paris Charles de Gaulle Airport as frontrunner the consortium kicked-off. The consortium aims to look for innovative and sustainable solutions to improve the environmental impact of the aviation industry (OLGA, n.d.).

STARGATE – Brussels airport taking the lead, as of 2021 this consortium started. The consortium focuses on the following goals: enhancing decarbonization, improve local environmental quality, simulate modal shift and creation of digital twin (Stargate, n.d.). This consortium has also published a catalogue for airports on actions to uptake SAF, this catalogue will be addressed later in the research.

ALIGHT – In 2020 the ALIGHT consortium took off with Copenhagen airport taking the lead. The aim is to introduce sustainable aviation solutions to airports with a focus on SAF, renewable energy sources and smart energy (ALIGHT, n.d.).

2.4. Diffusion of Innovation Theory & History of SAF Diffusion

There are multiple theories on diffusion on innovations, however the most popular and commonly referred to in science and literature is the theory proposed by Everett Rogers in his book of Diffusion of Innovations from 1962, Rogers argues that most innovations need long periods of time, mostly years since the innovation becomes available till the time it is fully adopted (Rogers, 1983). In this research the focus is on the technology adoption cycle and the type of adopters and their characteristics, this will be related to SAF diffusion.

Innovations are ideas, practices, or objects that are considered new by certain individuals(Rogers, 1983); this definition includes technologies or/and adoption mechanisms(Rogers, 1983). In the context of SAF and the uptake of SAF, we can consider SAF and the technologies revolving around it (feedstock types, the different conversion processes, and aircrafts) as the innovation that aims to be diffused widely. SAF has been used and around since 2007-2008, however its growth an adoption has been relatively slow(Hayward, 2022).

The diffusion theory is relevant in the case of SAF diffusion and uptake, to be able to understand how it has evolved throughout history. This allows to pinpoint barriers, challenges and opportunities that can arise in the future, moreover it puts in perspective how the mandate plays a role in the further uptake of SAF. The theory also allows us to see which relevant stakeholders are involved, it specifically allows us to see where airports can be placed and the role they play. Understanding the role of airports is crucial to be able to properly advise them and give them strategies that could be effectively implemented to further allow the uptake of SAF as an innovation. The terms and definitions provided in this section are revisited in the results section as part of the analysis.

2.4.1. A Brief History of SAF Diffusion

The diffusion of SAF and interest towards it has grown slowly, with only test flight being conducted in 2007, 2008 and in 2011 using biofuels combined with conventional jet fuel (Honeywell, 2022). In late 2008, a group of airlines that constitute 33% of the demand for commercial aviation fuel, and together with other aviation industry entities formed The Sustainable Aviation Fuel Users Group (SAFUG for short) (ICAO, 2008). The group committed to aid in the advancement of the uptake of SAF, including the development, certification, and the commercial usage of SAF as a drop-in fuel; additionally, the group set minimum sustainability requirements for the development of SAF and aimed at working together with governments, other industries, and the civil society, for knowledge sharing and to accelerate the usage of SAF (Boeing, 2008).

In 2011, the American Society for Testing and Materials (ASTM International) allowed the use of biofuels up to 50% blend in with conventional jet fuel using the HEFA conversion process (Enright, 2011). This permitted airlines to use such fuel for commercial flights; since then, between 2011 and 2015 over 2,500 commercial flights used up to 50% blend of biofuel coming from used cooking oil, algae, camelia and jatropha (non-edible oil feedstock) (IATA, 2023).

Between 2005 and 2011 a significant number of companies received hundreds of millions of dollars to research the extraction of fuel oil from algae and other sources, that showed promising expectations towards making such fuels competitive(Wesoff, 2017). Despite several forecasts, investments, and incentives given to produce biofuels there has been many companies failing to meet these expectations, several filing for bankruptcy, disappearing or shifting their business plans(AirportWatch, 2015; Wesoff, 2017).

It was only in 2016 that a portion of SAF was supplied through the hydrant system at Oslo Airport, in which multiple SAF fuel suppliers and producers were involved (SkyNRG, Neste and Air BP) (IATA, 2023b).Additionally, in 2020 Norway became the first country worldwide to introduce a mandate, which aimed at 0.5% of the fuel should be SAF(Pilling, 2021). After Norway, other countries are following their footsteps, such as Sweden, France and the United States, in which several of their airports offer incentives on SAF(Malicier, 2021).

In 2020 ASTM further published the seventh annex of approved SAF production processes(Green Car Congress, 2020). The certification by ASTM International was believed to help ramp up production and demand, a former vice president of Honeywell believed that by 2020 5 to 15% of the total aviation fuel supply would be coming from biofuels (Enright, 2011). Nevertheless, not much diffusion and adoption occurred throughout all these years, with few litres of SAF being produced worldwide; by 2019 SAF only made up 0.1% of the total jet fuel used (Pilling, 2021).

These past years, from 2019 up until now, several fuel supplier companies such as Neste, SkyNRG, AirBP, Gevo and many others have entered into partnerships with airports, airlines and other fuel suppliers with the goal to increase SAF production and deployment (Honeywell, 2022; Pilling, 2021). As of 2021, the European Union and the United States have both announced policy measures to boost the uptake of SAF, the EU with the ReFuelEU blending mandate and the USA with the Sustainable Skies Act aiming to provide SAF incentives(IATA, 2022b).

The latest data from 2021 by EUROCONTROL, reveal that approximately 0.05% of the total jet fuel consumption in Europe is SAF; with Norway having 0.50% of their consumption being SAF and 0.15% for Swedavia airports(EUROCONTROL, 2021). Historically airports have not played an active role in the diffusion of SAF up until now, nevertheless the development of consortium projects, specifically in the EU have shown airports could have a more active role in the uptake of SAF. Some airports have collaborated in test flights and pilot projects, and are currently still looking for such collaborations and involvement, which shows many are interested in being involved in the further diffusion of SAF.

2.4.2. Diffusion of Innovation Theory & SAF diffusion/uptake

As mentioned at the beginning of this section, Everett Rogers proposed the concept of diffusion of innovation, Rogers (1983) defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system". He also refers to *communication*, as the process where the participants generate, and exchange information between them to reach a consensus(Rogers, 1983). Rogers defines 4 main elements in the diffusion of innovation process, namely the innovation itself, communication channels, time, social system, and time; in the introduction the definition of innovation was given and this section provided that of communication, the concept of channels entails the means the information is delivered (Rogers, 1983).

The social system in innovation entails the combination of external and internal influences and stakeholders, these include the social structures, cultural context, role of the government, opinion leaders and agents of change(Rogers, 1983).Considering the diffusion of SAF, it is relevant to consider the definition of opinion leaders and agents of change. Opinion leaders are those who can influence other individuals' attitudes and/or their behaviours to some extent, they are able to give information and advice on the innovation to other members in the system (Rogers, 1983). Similarly, agents of change are individuals who can influence innovation decisions towards their desired outcome, they use opinion leaders as an aide in the diffusion of innovation (Rogers, 1983). Opinion leaders and agents of change can choose to slow down, prevent, or help the diffusion depending on their choices and own agendas(Rogers, 1983).

The element of time in the diffusion process is crucial, it can be described as the amount of time that needs to pass for an innovation to be adopted. Within the element of time, Roger defines 5 adopter categories related to how relatively early or late an individual will adopt an innovation within the social system, the following definition from the adopter categories have been adapted from those of Rogers (1983) and Moore (2014):

Innovators: These individuals are considered *venturesome or technology enthusiast*, and the first to adopt the innovation and can accept the uncertainties that come with it.

Early adopters: Considered *the visionaries*, see innovations or new technologies as a strategic opportunity and serve as role model to other members of the social system. They can become opinion leaders, and agents of change look for them to accelerate the diffusion process.

Early majority: They can also be called the *pragmatics;* they adopt the innovation before the average members of the social system and are rarely in leadership positions.

Late majority: These members of the social system are considered *the skepticals or the conservatives.* They adopt the innovation right after the average members of the system. They do not adopt the innovation until most members in the system have done so.

Laggards: Also called *traditional or skeptics* as well; these individuals are last to adopt the innovation and have almost no opinion leadership. They usually resist innovations and by the time they choose to adopt, a newer innovation might have already taken its place.

The Figure 9 shows the Innovation adoption cycle taken from Sinusoid (2021), in which the adopter categories can be seen in respect to the number of adopters versus how the technology matures or is adopted over time. As observed, the early and late majority category dominate the number of adoptions on average. Nevertheless, early adopters and the early majority might have a crucial advantage over the market and may gain opinion leadership positions.

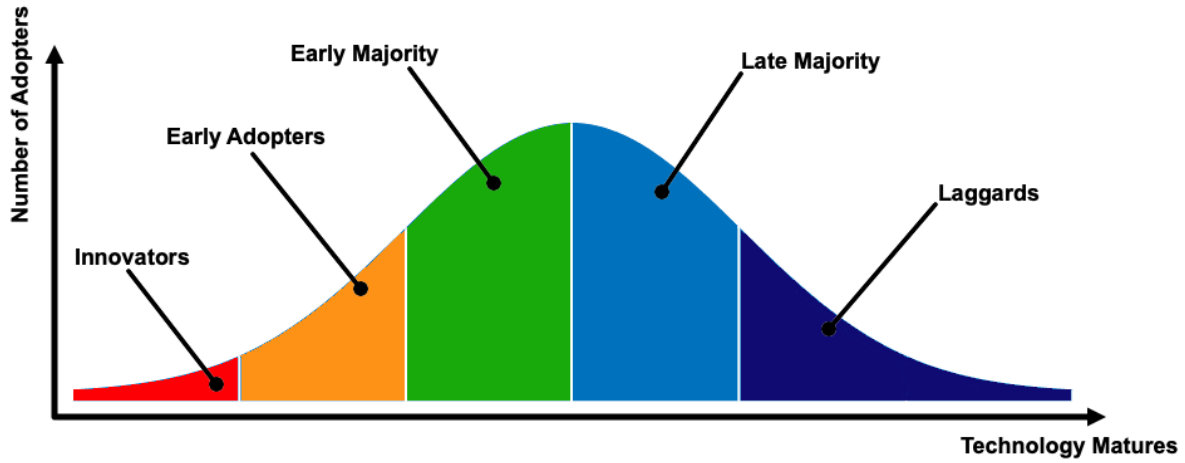


Figure 9: Innovation Adoption Life Cycle (Sinusoid, 2021)

In the context of SAF as the innovation, airports could potentially take the role of opinion leaders or even agents of change; this concept is further explored in the results section of this research. Airports as leaders, could play an enabling or facilitating role, by showing support to committed airlines on the usage of SAF(RBS, 2022); this can further increase their leadership position in the diffusion of SAF and within the decarbonization of the industry. Additionally, airports that can be considered early adopters or even innovators are further analysed in the results.

3. Methodology

The following section will cover the methodology that was used to help answer the research and sub-research questions of this thesis. Firstly, the literature review methodology is discussed, laying out how the academic papers, reports or/and news pieces were selected. Following this the methodology for the interviewing process, the interviewees and selection is explained. Subsequently, the stakeholder consultation which refers to the attendance to the SAF congress is described, primarily on how the notes taken were related to the interview results and the literature review. The literature review and the interviews were additionally analysed with the theory of diffusion provided in the background chapter. Finally, how these methods came together for the creation of the guide for airports on SAF implementation strategies is explained.

3.1. Literature Review

A literature review was conducted with the goal to gather a deeper understanding on what are the current trends in the sector are in relation to SAF growth, demand, and supply in relation to airports. Furthermore, current guidelines on SAF implementation in airports was looked at and compared, to identify gaps and common objectives that can be applied in European airports. News articles were accessed, reports and academic papers primarily in relation to SAF diffusion and uptake strategies. Some literature on general expectations and opinions on airports were also included, together with one review on airports and innovation and one on innovation facilitators.

The literature review and the research provided in the background chapter were the primary source of information and building block for this research. The information gathered aimed to help create the interview questions and lay down the first steps on understanding the entire SAF context within airports. The results of the literature review, together with the background information helped answering the sub-research questions and map certain concepts for the formation of the guide. The focus of the guide is helping airports understand their position and placement within the ReFuelEU mandate and SAF implementation.

The literature review results were put in a table (Appendix III: Literature Review), providing the title of the literature reviewed, the author(s), the key search words used, the key findings from the review, and the main advice and outcomes. The results from the table were then analysed considering the sub-research questions as a baseline, and with the main research question in mind. Additionally, the diffusion of innovation theory and the adaptor categories were considered in the analysis.

3.2. Interviews and Stakeholder Consultation

To further strengthen and support the information found in the literature review, interviews were conducted. The participants of the interview were reached out through email, LinkedIn and primarily in person during the Sustainable Aviation Futures Congress Europe 2023, the interviewees were asked to fill in and send back an informed consent form (Appendix I: Informed consent form) prior to the interview, some interviewees gave verbal or written consent to the interview. The interviews followed a semi-structured format, meaning some of the questions were predetermined, nevertheless there is flexibility on how the questions are asked, the order they are asked and spontaneous can be asked depending on the responses from

the interviewees(Tegan, 2022). Semi-structured interviews allow one to see certain patterns and make relevant comparisons between the responses from each interviewee(Tegan, 2022). The questions were formulated considering the sub-research questions, the scope of the research, the knowledge gaps on the topic and each interviewees role/knowledge. In Appendix II: Interview Sample Questions some of the questions used for the interviews can be seen, as the questions asked varied per the stakeholder category that was being interviewed. This was done since not all the questions were relevant in all the cases, and some questions needed to be modified depending on the person being interviewed and what their expertise were.

The interviews were conducted over Microsoft teams, they were recorded and transcribed automatically. The transcriptions were then checked together with the recording to correct certain words, terms and to improve the accuracy of the transcription. After the transcriptions were checked, each interview was then assessed considering the background of the research, the literature review, and the congress notes. This was done to gather the main outcomes, relevant information mentioned, additional questions the interviewees had for the future, and main challenges/barriers that were mentioned during the interviews. This was then placed in a table for a summarized overview of the results, which can be seen in Appendix IV: Interview Transcription Summary Table in detail. The analysis of the table was done in the results section in Chapter 5. To preserve the privacy of the interviewees, the entities they work for, and their names were anonymized, therefore, the transcripts of the interview are not included in the research. As mentioned, in Appendix IV, the summary of the interviews and the main outcomes can be seen.

Table 4 below, displays the interviews that were made for this research, they were categorized on the field they work on within the aviation industry, the stakeholders/experts that do not work directly in the field were categorized separately. The categorization can be seen in the table, the fuel supplier's category has 3 interviewees each from different companies, different sizes, and roles. The category of airports includes 5 interviewees from different airports and consortiums, and 1 airport investor company, their roles also vary; the interviewees belonging to airport consortiums were additionally crucial for the research, due to their ongoing activities and projects surrounding SAF and related innovations for the decarbonization of the industry. The airlines category includes 3 different airlines, each of different size, the interviewees have a role specifically in relation to SAF and projects of SAF usage for the aircraft (this includes either mass balance approach or book & claim). The last category involves expert and academic interviewees in the field of SAF or biofuels in total 5 interviews were conducted for this category. These include: an academic professor who attended the congress was interviewed, an energy consultant in the transport sector from a governmental agency, a SAF/fuel expert, an airport consultant/strategist, and a sustainability consultant.

The table columns show, the stakeholder/expert categorization, explained above; additional to this the interview 'name' is provided, as the actual names were anonymized a general description of the entity, they represent is given. To facilitate the referencing of the interviewees responses in the analysis of the results, simplified reference code names were assigned, these can be seen in the table. The last column of the table describes the role of the interviewee within the entity they represent, this was to understand their positioning and align the questions asked depending on this role.

Table 4: Interviewee Categorizations and Interviewees

Stakeholder/expert categorization	Interviewees	Referencing Code	Role
Fuel Suppliers	SAF producer and distributer 1	Fuel Supplier 1	Head of Capacity Development
	Multinational oil and gas company	Fuel Supplier 2	Business developer for SAF
	SAF producer and distributer 2	Fuel Supplier 3	Business developer for SAF
Airports & Airport Consortiums	Large airport in the Benelux area and related consortium	Airport & Consortium 1	Project Manager & Sustainability Manager
	Large airport in Scandinavia and related consortium	Airport & Consortium 2	Head of Sustainability Development
	Civil airport operator in Scandinavia and related consortium	Airport & Consortium 3	Senior Advisor
	Private industrial airport investors and managers	Airport asset manager 1	Senior Asset Manager
	Large Airport in Benelux area and related consortium	Airport & Consortium 4	Sustainability Advisor
	Large Airport in Southern Europe	Airport advisor 1	Energy Transition & Decarbonization Advisor
Airlines	Ultra-low-cost carrier	Airline 1	Sustainability Manager
	Low-cost carrier	Ariline 2	SAF portfolio Holder
	Flag carrier	Airline 3	SAF Manager
Experts and Academics	University – Academic Sector	Expert 1	Associate Professor in Aviation Management
	Emission Authority – Governmental Body in the Netherlands	Expert 2	Energy for Transport Consultant
	Independent Consultant	Expert 3	Sustainability Consultant
	Engineering Consultant	Expert 4	Fuel expert and consultant
	Airport Consultancy	Expert 5	Airport Strategist

3.2.1. Stakeholder Consultation - Sustainable Aviation Futures Congress

The Sustainable Aviation Futures Congress (SAF Congress) was a three-day event in which 450+ attendees from the aviation industry were present. The congress brought together industry experts and stakeholders to discuss the future of aviation and its path toward sustainability and decarbonization (Sustainable Aviation Futures Congress, 2023). This year due to the release of ReFuelEU Aviation initiatives led the main topics of discussion and was of high interest among attendees. There were multiple panels and keynotes that provided relevant information on SAF uptake, policies, challenges, and opportunities for the industry. The attendance to the congress was made possible by NACO and their participation on two different panels.

The information gathered at the conference was by taking notes and accessing the presentations made available by the congress through their app, the notes taken can be seen in Appendix V: Personal Notes SAF Congress. This information was used to look deeper into topics mentioned by the industry experts and compare these with the literature review.

According to Greer et al., (2020), there is a disconnect between exploratory work and the implementation of sustainability-related practices by airports; therefore, the comparison is crucial to see this disconnect between the findings in the literature review versus what was heard during the congress and in the interviews.

The attendance to the congress was relevant to connect with most of the interviewees that agreed to participate in this research. The use of the information from the congress will be cited accordingly and was considered critically since the gathering of information was mainly through notes by the researcher, therefore the notes could contain unintended bias and misunderstanding of what the panellists said. Nevertheless, the information was useful to further investigate factors that were not considered before and to further formulate questions for the interviewees.

3.3. Guide for Airports for SAF Strategy Implementation

The output from the literature review, interviews and strengthening it with the knowledge gathered from the SAF Congress were the backbone on creating a guide for airports for SAF strategy implementation. The guide helps summarize the main results gathered from the literature review, the congress notes and the interviews. It aims to showcase what airports have to consider in order to implement strategies for the uptake and diffusion of SAF, considering the ReFuelEU mandate. Furthermore, using the innovation theory, potential roles airports can take is explored.

The guide is presented in form of a figure, this can be used to provide advice to airports, help them identify their role, certain actions that can be implemented and certain desired outcome depending on the innovator role they choose to partake. The guide can be then used to generate detailed and custom-made roadmaps depending on the airport and the role they aim to play in the future, aligning the advice with their own targets and strategies considering their own partnerships and surrounding environment or context.

4. Literature Review

This chapter will layout the analysis of the results and findings from the literature review performed, relating it to the innovation theory and the adaptor categories shown in Figure 9F. The extended literature review can be viewed in the form of a table in Appendix III, the table shows the main outcomes of the literature review, the table displays the title of the paper, website, journal, report, or article reviewed, the author, the search words used, the key findings from the reviewed papers and the main advice or conclusions taken from the reviews made.

The findings of the literature review show some airports have tried to take the lead in the diffusion and uptake of SAF; several airports have even taken part as innovators or have partnered with innovator fuel suppliers or airlines that have shown an early interest in the implementation of SAF in their voluntary targets. Several of the literature reviewed give advice and guidance to airports on how to support the decarbonization of the industry, this also includes solutions such as SAF, even though there is no direct economic gain on SAF uptake for airports there are several benefits for them as well(ACI Europe, 2022; ACI World, 2021; Baldanza, 2023; de Haes et al., 2022; Santos & Delina, 2021; Vuckovic & Puls, 2022).

As mentioned in ACI World (2021) strategy for airports, the role an airport can take on in supporting SAF will depend on its circumstances, this includes the local context, the degree of influence they have in their own operations, and the external factors, such as the political, economic and the regulatory context. These factors will influence how much an airport can favour the implementation of SAF; there are multiple airports that have been able to provide incentives to airlines or collaborate with SAF fuel suppliers due to the specific conditions that surround them(ACI World, 2021; Ahlgren, 2022; De Haes, 2022; Surgenor, 2023).

The literature reviewed showed that incentives are preferred by airlines, and many of the leading airports on SAF uptake and deployment have had contextual and political advantages in making such incentives possible(ACI Europe, 2022; ACI World, 2021; Ahlgren, 2022; Santos & Delina, 2021; Vuckovic & Puls, 2022). Nevertheless, airports can still use their unique positioning in the industry to connect the rest of the members of the system and aid them in the transition toward net zero(Ahlgren, 2022). As mentioned in the section on innovation diffusion theory before, some members of the system, such as the opinion leaders can either block or aid the diffusion of an innovation(Rogers, 1983). In the case of SAF and considering that airports could use their unique positioning to become opinion leaders and aid the other members of the system in the diffusion and uptake of SAF; otherwise, airports could possibly block or hinder the smooth implementation of SAF within their terrain and general operations.

Depending on how airports have been involved with other stakeholders and members of the system can help them define their role and the actions they can take. Airports can become facilitators when it comes to SAF-related actions (delivery, projects, test flights) (Vuckovic & Puls, 2022), coordinate with the different stakeholders, and increase partnerships with airlines, fuels suppliers, and policymakers (Ahlgren, 2022; Baldanza, 2023; ICAO, 2017; Santos & Delina, 2021) . Facilitators as part of the innovation diffusion life cycle are crucial, the presence of facilitators helps educate, advocate, and advise the other members of the innovation system(Johnsson, 2018). Innovations and innovation teams can benefit from facilitators as their role is to support, coach, and facilitate them through the diffusion and implementation process(Johnsson, 2018). Currently, the research on how airport innovation can be achieved is limited, primarily due to the lack of collaboration between innovation scholars and specialists(Kiliç et al., 2021). Airports are being pushed to innovate in many aspects, focusing

on safety, passenger experience, planning, and financing(Carlson, 2021) ; nevertheless, innovations supporting sustainability are becoming increasingly relevant as passengers, activists, NGOs, and the public is pressuring the industry to act(Opare Mintah, 2023; Vuckovic & Puls, 2022). Many of these NGOs and environmentalists consider airports should be more ambitious and proactive when it comes to Scope 3 emission reductions targets(Surgenor, 2023), which include emissions generated from airlines. Even though airports do not directly control Scope 3 emissions, they are able to influence them, in the case of SAF they are able to introduce certain mechanisms or partnerships to incentivize the usage of SAF at the airport(Surgenor, 2023).

The increasing interest on SAF by the industry comes with several challenges and concerns, with many factors not being fully considered. The literature has revealed that for SAF to become mainstream and provide the high volumes required by the industry, costly investments will be needed(Baldanza, 2023; de Jong et al., 2018; Gelles, 2023). Fulfilling such demand on SAF will not only be costly but difficult in terms of scaling up production and feedstock availability(Gelles, 2023). In addition to this, competition for SAF between countries/regions and the feedstock for biofuels in general will likely impact the ramp-up of SAF in the aviation sector in the EU. Even though rising policies on SAF in the Europe and USA are driving up investments on the market, competition between countries and regions will become problematic(Gelles, 2023; Santos & Delina, 2021; Surgenor, 2023). Several sectors which have employed the usage of biofuels for longer, such as the road transport sector, impose additional competition to the SAF industry (de Jong et al., 2018); such interactions between not only industries but existing policies on the usage of biofuels must be considered in the long-term(de Jong et al., 2018). As SAF production and usage become popular, the industry should not rely on it as the sole solution to achieve decarbonisation(Baldanza, 2023).

5. Interviews & Stakeholder Consultation

The following chapter gives an overview and analysis of the main outcomes and the relevant information that was gathered from the interviews and the personal notes taken from the SAF Congress. Appendix IV: Interview Transcription Summary Table shows the summary of each interview which was inputted in a table; the table was used to create an overview on the main outcomes and the relevant information taken from the interviews. Additionally, main concerns, challenges and questions interviewees had or mentioned were identified and added to the table. This was then analysed together with the personal notes taken at the SAF Congress (refer to Appendix V: Personal Notes SAF Congress), the results of this analysis from the table and the comparison of it to the notes are described in this chapter.

The first aspect identified from analysing the interviews, was that airports are not part of the fuel purchase supply chain, they do not purchase or buy fuel themselves which leaves them out of the equation (Fuel Supplier 1 & 2; Airport & Consortium 2; Airline 1; Expert 3, personal communications, 2023). Therefore, their role has been debated within the mandate and stakeholders. Even among airports themselves, their role is debated and remains unclear for them (Airport & Consortium 1 & 2, personal communication, 2023); the consortiums interviewed mentioned they are still questioning how their role will develop over time or what it should be with the coming mandate (Airport & Consortium 1,2 &4; Airport asset manager 1, personal communication, 2023). Many identified that airports struggle to find their role within the ReFuelEU mandate, as mentioned by the interviewed Airport & Consortium 1(personal communication,2023) the mandate does not provide clear specifications on what the airports' obligations will be. Furthermore, the organization of the airports' fuel infrastructure is quite complex; most airports do not own or operate the fuel infrastructure within the airport and the organization of the infrastructure varies per airport (Fuel Supplier 1, 2 & 3, personal communication, 2023).

The mandates obligations on SAF primarily fall on to the fuel supplier and aircraft operators, nevertheless, airports are required to ensure the fuel infrastructure is safe and ready to deploy SAF. As mentioned, many airports do not own or operate the fuel infrastructure, they only provide the land for such infrastructure to be built and operated (Expert 3, personal communication, 2023). In many cases the fuel infrastructure is operated and owned by a consortium of airlines and fuel suppliers, multiple partners, or third parties (Fuel supplier 1&3, personal communication, 2023); conversely, the airport gives out licenses to operate the infrastructure on the airport (Fuel supplier 3, personal communication, 2023), and some airports have limited control on fuel operations (Expert 3, personal communication, 2023). Therefore, the obligation to ensure the infrastructure for SAF supply to be ready does not fall on the airports' responsibility in some cases. The interview with Fuel Supplier 2 and Airline 3(personal communication, 2023), mentioned that airports should not take upon such responsibility and leave fuel suppliers to take care of infrastructural technicalities and changes when it comes to SAF. When it comes to infrastructural changes for SAF deployment, interviewees confirmed that no infrastructural changes are required for SAF implementation per the mandate, some cases could require minor changes but do not pose a risk to the rest of the operations (Fuel supplier 2; Airport & Consortium 2, 3 & 4; Airport Advisor 1; Expert 1 & 4, personal communication, 2023).

During the SAF, Congress the role of airports was brought up as well, with many questioning what their added value is in the SAF value chain and how their role should unfold considering the mandate(de Haas et al., 2023). Some different views on the role of airports were additionally brought up by airlines, most have not considered airports as taking up an active role, primarily because airlines are focusing on securing SAF supply, concerned about greenwashing backlash, and on ensuring book & claim mechanisms are set (Keszei et al., 2023). Additionally, they mostly voiced interest and preference for airports giving SAF incentives to them; several other speakers representing airports or consortiums, reinforced this, as part of their experience with airlines and SAF uptake(Bauen et al., 2023; Covrig et al., 2023; de Haas et al., 2023; Forster et al., 2023; Keszei et al., 2023). The interview with Airport advisor 1(personal communication, 2023), confirmed that as airlines prefer incentives for SAF from airports, the question still stands on who will pay for the SAF. Many airports are not able to provide financial incentives, due to lack of funding, shareholders not seeing a business case for it, or not seeing any gain from providing such incentives (Airport asset manager 1; Airport & Consortium 1,2&3; Airport advisor 1, personal communication, 2023).

Despite airports being uncertain about the role they should play, as they are not part of the value chain and have no direct benefit from SAF implementation, there are roles that were identified during the interviews. Fuel supplier 1 & 3(personal communication, 2023) both touched upon the fact that even though airports have a limited role within the supply chain they are still an important stakeholder and could play a role in the long term. The interviews with the Fuel Suppliers (Fuel Suppliers category, personal communication, 2023), identified that airports could be facilitators in the transition period and during the deployment of SAF, enable fuel suppliers by helping them access or map out the infrastructure or advocating/lobbying for SAF within their context (governmental bodies and shareholders). Airports themselves and representatives (Airports & Airport Consortiums Category, personal communication, 2023), mentioned they could play a role in educating passengers and creating awareness of SAF; furthermore, they identified that they could take upon an advocating role in supporting SAF implementation in their operations by supporting policies, they can also enable or coordinating certain aspects of the operations. They additionally mentioned they can get involved in external innovations or projects on SAF by becoming facilitators, connecting fuel suppliers with airlines, and helping them engage with each other and other partners.

The airlines interviewed (Airlines Category, personal communication, 2023), agreed that airports can help in educating passengers on SAF, promoting SAF among passengers, and taking upon the role of facilitator, helping in the ramp-up of SAF. Additionally, they mentioned airports can aid in encouraging projects, such as test flights, partake or invest in other sustainability projects together with airlines, and collaborate/cooperate with other stakeholders. The airlines further highlighted the importance of airports preparing their infrastructure for future alternatives such as hydrogen and electric flights, as well as paying attention to future innovations and technologies that can further help in the decarbonization of the industry. Lastly, airlines have indicated that airports should maintain openness to cooperate and help with SAF while also collaborating and sharing knowledge among airports and other stakeholders (such as fuel procurement teams in airports collaborating with their counterparts in the fuel supplier and aircraft side).

In the interviews with experts, (Experts and Academics Category, personal communication, 2023) the role of airports as lobbyists was highlighted, describing that such role could have advantages in supporting the deployment of SAF; they additionally mentioned airports as facilitators, aiding in the planning for the future technologies of fuels and aircrafts. Lastly,

experts mentioned the involvement of airports in policies is crucial as they can aid in favouring SAF and speed up its deployment. Experts in the interview (Expert 4, personal communication,2023) suggest airports as facilitators should stay constantly informed on SAF mandates and try to participate in the supply chain. Additionally, the experts, as well as fuel suppliers and the airlines (personal communication, 2023) have suggested airports can already help in doing inventory on the fuel infrastructure, checking on what is needed, who owns it and other technicalities.

As mentioned by Airline 3(personal communication, 2023), the role of airports depends on their own strategies and who owns the fuel infrastructure; moreover, Airport & Consortium 4 (personal communication, 2023) voiced that the role of airports and involvement in the uptake of SAF also depends on their local and national context. Several airports have had advancements in SAF implementation and uplift, many have participated in projects (particularly consortium related) and collaborated/facilitated in SAF special deliveries or pilot flights. These airports have taken advantage of their specific circumstances and surroundings, this was especially identified with airports such as the Teesside airport(Forster et al., 2023). They have taken several opportunities to adapt and become front-runners/early-adopters in the SAF scene, they have explored their surrounding context and taken advantage of their unique position. Currently, they have invested in SAF projects, having a supplier and refinery of SAF close to the airport(Forster et al., 2023).

The airlines, airports, and fuel suppliers showed concern about the competition for SAF, airlines will want the SAF that is cheapest which also poses pressure and uncertainty on the sustainability of the SAF delivered; this concern on the sustainability of SAF to meet the growing demand was also acknowledged by all the interviewees. Concern from both airports and airlines was shown during the interviews and the SAF congress, on SAF deliveries, it is expected that fuel suppliers will deliver SAF where incentives are in place, where they can sell the most amount to airlines, or to airports close to a refinery, which would leave non-hub airports at a disadvantage on SAF quantity and availability(Fuel Supplier 2 &3; Airport & Consortium 2 &4; Airport asset manager 1, Airport Advisor 1, Airline 1, 2 & 3, Expert 1, personal communications, 2023). Additionally, there is uneasiness on the competition for feedstock and SAF availability between nations (USA, UK, and EU) and industries (road, chemical, aviation, etc). In the interview with a representative from the road transport sector (Expert 2, personal communication, 2023) highlighted that biofuel mandates have been for a longer time in several EU countries, once the ReFuelEU is introduced it is likely there will be interactions and competition for biofuel between the industries. This was mentioned as well by Airport Advisor 1(personal communication, 2023), the transport sector has been receiving biggest portions of biofuel and the feedstock volumes historically and this is expected to keep growing as the transport industry is also aiming for decarbonization.

There are many unknowns and questions that remain unanswered, which cause more stress and pressure on the stakeholders and the aviation sector in general. As mentioned by Airport & Consortium 4(personal communication, 2023), large uncertainties generally are not a good indicator, setting up SAF supply chains requires years of planning and strategies since it is a long-term industry. Generally changing such complex supply chains takes longer than most think, therefore there might be many challenges and risks ahead that the industry and the EU have not yet considered. In the interviews, it is clear that most interviewees have questions about the ReFuelEU mandate and how it will unfold, as mentioned most airports struggle to see their role in this as there is much uncertainty. The airlines interviewed also showed concern about how the mandate will be implemented and what details they need to look out for. The

fuel suppliers are unsure how the mandate will ensure the obligations are fulfilled or how the penalties will be implemented, most understand the penalty will be hefty and costly (Fuel Supplier 1, personal communication, 2023). Lastly, both in interviews and the SAF congress identified the importance of collaboration between all stakeholders, as the decarbonization of the sector is a common goal and can only be achieved with proper collaboration and engagement among all parties.

6. Results: Guide for Airports for SAF Strategy Implementation

The analysis of the literature review together with that of the interviews and the SAF congress notes, come together in this chapter to give answers to the sub-questions of the research. Here, the analyses were compared and combined to be able to fully comprehend the situation and landscape of airports within the SAF scene and the ReFuelEU mandate. The combination of the literature findings with those of the practical industry and stakeholders shows an understanding of the importance of airports' context and the industry itself. The following paragraphs will cover the results per sub-research question topic in five different sections (1 section per question), subsequently, the results come together for the creation of the guide which is explained at the end of this chapter.

The term 'context' is substantial to the results and is frequently used in the following paragraphs; it is crucial to understand that in this research this term employed involves several aspects in relation to the surrounding environment of an airport. By this, the term 'context' is used to generalize conditions the airports belong to and encounter in relation to SAF deployment/implementation, such context can benefit or pose a certain disadvantage to airports. This context varies per airport on local, regional, national, and international levels; each level imposes a different set of interactions on each airport and should be carefully considered.

Role of Airports

The role that airports choose to take can vary and might have different impacts on the strategies they can choose from. In the interviews and SAF Congress both outlined the role for airports, the roles that was identified and mentioned the most was: the enabler and/or facilitator role. This was supported by some of the literature reviewed, additionally, the role of the facilitator in innovations was looked at, which showed the importance of facilitators within innovation teams for the success of the innovation. Airports as enablers or facilitators can be more vocal and involved within the supply chain by supporting and aiding other stakeholders; their positioning allows airports to connect the stakeholders as they are in a way the connecting entity between fuel suppliers and airlines. Airports provide the general facilities and land for such stakeholders to interact; with airports acting as active facilitators/enablers which can speed up the implementation of SAF within the airport. Additionally, airports can provide indirect support by promoting SAF in their terminals, educating passengers on what SAF is, book & claim, or mass balancing mechanisms, and tying this to sustainability/decarbonization efforts. Generally, passengers spend a significant amount of time at airports or terminals, therefore certain facilities in such areas can be used to implement educational material on SAF or sustainability in general.

The interviews and SAF Congress mentioned other roles which airports could be involved in, namely lobbying, and advocating. Many noted the need for airports to become more proactive in their involvement with local and national governments when it comes to SAF and additional innovations (such as hydrogen and electric). Their involvement in such roles can generate an additional push to governments into aiding the industry by means of incentives or additional policies; lobbying and advocating can additionally position airports to favor and speed up SAF implementation strategies among the industry.

ReFuelEU Impact on Airports Infrastructure & Operations

The mandate currently requires airports to ensure the infrastructure and safe implementation of SAF within their system. Nevertheless, from the analyses made in the previous chapter, it was identified that many airports do not own or operate their fuel infrastructure; moreover, who owns or operates such infrastructure varies from airport to airport. In some cases, the infrastructure is owned by a consortium of airlines and fuel suppliers, by only fuel suppliers or they are fully operated by third-party institutions. The airports may provide the land for the infrastructure or the infrastructure itself but the operation of it might fall out of their own operational scope; therefore, the mandate does not provide sufficient detail on how this should be dealt with, or what additional steps airports should take to support this.

Even though airports might not own the infrastructure for fuel supply, SAF as a blend-in fuel does not require any infrastructural or operational changes; as it can be safely used and injected into existing infrastructure without additional (major) modifications, and it can be handled exactly as Jet-A1 fuel. One interviewee indicated that minor changes were needed for SAF to enter the airport infrastructure but did not pose a toll on the full operation and implementation of SAF.

Several interviewees and speakers at the congress did show concern about the impact on the infrastructure once e-fuels or 100% SAF is implemented or used. This will likely require notable infrastructural changes that will require higher investment costs, nevertheless, this remains unknown. Additionally, there is uncertainty among stakeholders on the transition of the fleet (aircrafts that can use 100% vs those that cannot) and how this will look organizational, operational-wise, - and their infrastructure. As for blending on-site capabilities, currently experts advise against it; primarily for safety concerns on the fuel quality and the additional costs or investments needed to implement a blending facility on site. Consequently, in the short-term blending on site is not recommended or viable, this could change if other SAF conversion technologies become mainstream and economical, still this will only be possible in the long-term scope.

Front Runners vs. Late Adaptor Airports

Considering the innovation theory from chapter 2.4, it is clear that airports that have been front-runners, innovators, or early adaptors SAF uptake have had an advantage in implementing some strategies, especially when it comes to incentives. It was observed that most of these airports providing incentives are partly owned or wholly owned by the government, which could pose an advantage to them, versus to those who are privately owned. This was further mentioned during the congress and in various interviews, many privately owned airports view publicly owned airports as overall more advantageous when it comes to the implementation of SAF strategies. In the literature review, it was identified that this is not always the case, Heathrow airport is privately owned, and it has been one of the world's leading airports on SAF uptake incentives, having a fund set up specifically for this.

Airports that can be considered front-runners, who have partaken in multiple initiatives, projects, partnerships, and consortiums in relation to SAF uptake, are in such a position because of the system and context they are in. These airports have taken advantage of their unique positioning, to adjust and lead the uptake of SAF. This was seen for example during the conference with the Teesside airport, whose circumstances have allowed them to closely

collaborate with SAF innovations and projects. Several other airports have notably taken voluntary steps towards being involved with SAF uptake; nevertheless, this solely depends on the context they find themselves in.

As mentioned, the positioning of the airport on how advanced or involved they are depends on their context. This means airports must assess their context and surrounding landscape to be able to visualize what options are available for them and see what actions or steps are within their reach to boost SAF diffusion. An important factor that heavily weighs in the context of the airport and how it uses such context to its advantage decision maker or makers of the airport; the decision maker(s) will ultimately decide how to act or react to the context and environment it finds itself in. In the context of SAF diffusion and uptake, the decision maker(s) can either use their context to favor this or not. The context is additionally influenced by several aspects, the following points were identified from the analyses made on which are some of the aspects that should be considered in the context of an airport:

- Who owns the airport and what is the decision-making process of the airports (who makes the decisions)?
- What are the interests of the airport and what commitments they have made (including interests of the CEO and/or shareholders)?
- What is the political environment? What policies help or hinder the implementation of SAF? What are the local or national interests (on SAF)?
- What partnerships does the airport have? Are they involved in any projects or consortiums in relation to SAF?
- Who are the stakeholders and what are their interests? Do their interests and those of the airport align?

SAF implementation Trends, Opportunities, Barriers & Risks.

Currently, the industry shows much uncertainty and concern about the unfolding of the ReFuelEU mandate, still, there are many unknowns that remain unanswered. This was clearly identified from the interviews and the Congress attendance, where the stakeholders and experts raised many questions and challenges that have yet to be addressed by the mandate. As a main challenge and risk many stakeholders, including airports showed concern about the sustainability mechanisms supporting the mandate, such as the book & claim, and mass balance systems. There is not one overarching mechanism that ensures no double-counting or ensuring proper emission reduction claims from the mechanisms; additionally, it is unclear if airports will play a role in issuing certain SAF certificates or claims, or who will oversee issuing such documents.

Additionally, ensuring the sustainability of SAF and the feedstocks used for it is being debated among the industry stakeholders on how the sustainability criteria will be met to match the demand; mainly when other industries will also be competing for the feedstock and fuel, such as the road transport sector which has used biofuels for a longer time. Competition for feedstock and the industries might not affect airports directly, nevertheless, it might influence how airports compete between them. The competition between airports regarding SAF is essentially on the knowledge gathered, partnerships that are fostered, and involvement in projects. This competition hinders the proper collaboration between airports and their partners, affecting the exchange of information when it comes to SAF implementation strategies. Collaboration between consortiums, airports, and stakeholders is key for the proper diffusion

of SAF in the long-term to meet the goals of the mandate. Sharing discoveries and knowledge between them can speed up the process, enabling SAF to become mainstream in the future.

During the interviews and the Congress, many airport representatives mentioned or identified that their shareholders currently do not see a business case for sustainability in general and SAF implementation. This has posed a barrier to many airports to become more proactive in several sustainability areas, such as SAF implementation strategies or the provision of SAF incentives to airlines. If SAF or sustainability actions are not within the interests or are aligned with the goals of the airports' shareholders, there is more hesitancy in them playing a role within the mandate or becoming involved in the supply chain of SAF. As many shareholders and decision-makers within the board of airports do not see an economic gain on becoming proactive, it obstructs the proper deployment of SAF as an innovation. This poses a risk in fulfilling the mandate in the long-term and discourages fuel suppliers from providing SAF to certain airports if there is no support from airports. Thereby it might affect how future-proof or adaptable the airport becomes to other sustainable innovations, causing a delay in the decarbonization of the aviation sector.

Airports could use certain opportunities on SAF mandates and trends to become more attractive to other stakeholders and airlines. They can use their enabler or facilitator role, together with the knowledge of their specific context to attract certain projects or motivate stakeholders to investigate SAF implementation. Furthermore, opening up to SAF strategies can facilitate the future implementation of other technologies within their facilities, such as hydrogen and electric flights. Another opportunity that was identified in the analyses from the previous chapter, involves airports becoming energy hubs for the future. SAF can be seen as a steppingstone to other alternatives, such as airports becoming energy hubs and electrifying their operations; these actions that move to decarbonize the industry attract other stakeholders to be involved, this can include SAF innovations.

Current Best Practices

There are several best practices on SAF implementation strategies not only in Europe but worldwide as well, the research showed that most stakeholders excluding airports, favour incentives as the best practice to motivate airlines and/or fuel suppliers to uptake or provide SAF to the airport. The utilization of incentives has been adopted by several airports; however, this has caused worry among some airports. Airports with incentives might be able to attract more volumes of SAF and airlines uptaking SAF, leaving airports without incentives at a disadvantage. Airlines will likely opt to uptake SAF where it is cheaper or where there is more availability; many airports are not currently able to provide such incentives due to their circumstances and context. A few airports have had a contextual advantage and means to additionally invest in SAF-related projects outside the airport, for instance, investments in SAF refineries, blending facilities nearby, research into alternative conversion technologies, or into feedstock extraction projects. Nonetheless, such investments and economic actions depend on the contextual advantage of each airport and how they choose to act in their context.

Despite that, there are other practices airports can deploy without providing significant economic aid to airlines. Most of the best practices identified in the research involve airports collaborating with stakeholders in the supply chain or with consortiums, such collaborations and proactiveness have facilitated test flights or projects concerning SAF within the airport. Their positioning in the industry and their neutrality in the fuel supply chain can allow them to connect stakeholders and facilitate collaborations with each other. Similarly, they can engage

passengers by educating them on the mandate, SAF usage, and the decarbonization of the sector.

The literature reviews showed there is a significant amount of information on best practices and strategies for airports to look at when it comes to SAF implementation. There are several reports, papers, and even catalogues available suggesting SAF implementation strategies for airports, such as the STARGATE catalogue for airports. Nevertheless, the interviews and the Congress showed such practices and strategies that are available are not being widely implemented or replicated; by looking at the results already described above it is clear this is primarily due to the uncertainties on the mandate and the undecided role of airports within the supply chain. Airports must understand their context within their mandate and their role to be able to then look at the solutions that are already out there. Moreover, many airports and their shareholders do not see any significant economic gain or benefit from partaking in such implementation practices; as mentioned in the interviews and by several speakers in the SAF Congress, the goal to achieve decarbonization is a common goal and it requires all parties from the industry to collaborate to achieve the targets from ICAO, ACI and EU.

Guide for EU Airports for SAF Strategy Implementation

These results described above have been placed in form of a short guide, shown in Figure 10 below; this serves as basic guidance for airports to follow for them to understand their positioning and role within the implementation of strategies in relation to the ReFuelEU mandate.

The guide should be considered critically, it is not a one-size fits all guide, all airports are different in nature due to their context, not only on location and size, but the industry poses many different complexities and uncertainties that affect the operations of the airports differently. Therefore, this guide presented shows a general, and straightforward advice that can serve as a guideline for supporting airports in making well-informed strategic decisions, corresponding to the current diffusion of SAF.

The Figure 10 shows six key considerations airports should consider before looking into which strategies they could implement, depending on which role they want to take and how active or innovative they want to be regarding the ReFuelEU and future technologies. The six key considerations are a result of grouping crucial results from the analysis of the literature review, interviews, and stakeholder consultations. Each consideration has key elements which explain what action should be taken or what question should be answered, the following paragraphs explain these considerations in detail. The steps 1 to 5 shown in the figure are each directly linked to the results described above and the 5 sub-questions presented in this research; as for step 0, this is included due to the importance and relevance for airports to first comprehend the mandate and its impact on them before any other actions are taken. Only once the mandate and the policies are understood by the airport, can the other steps be considered.

The title of each step shown in the figure (the coloured boxed) describes the general goal of the step that aims to be achieved, below the title the boxes define certain actions and

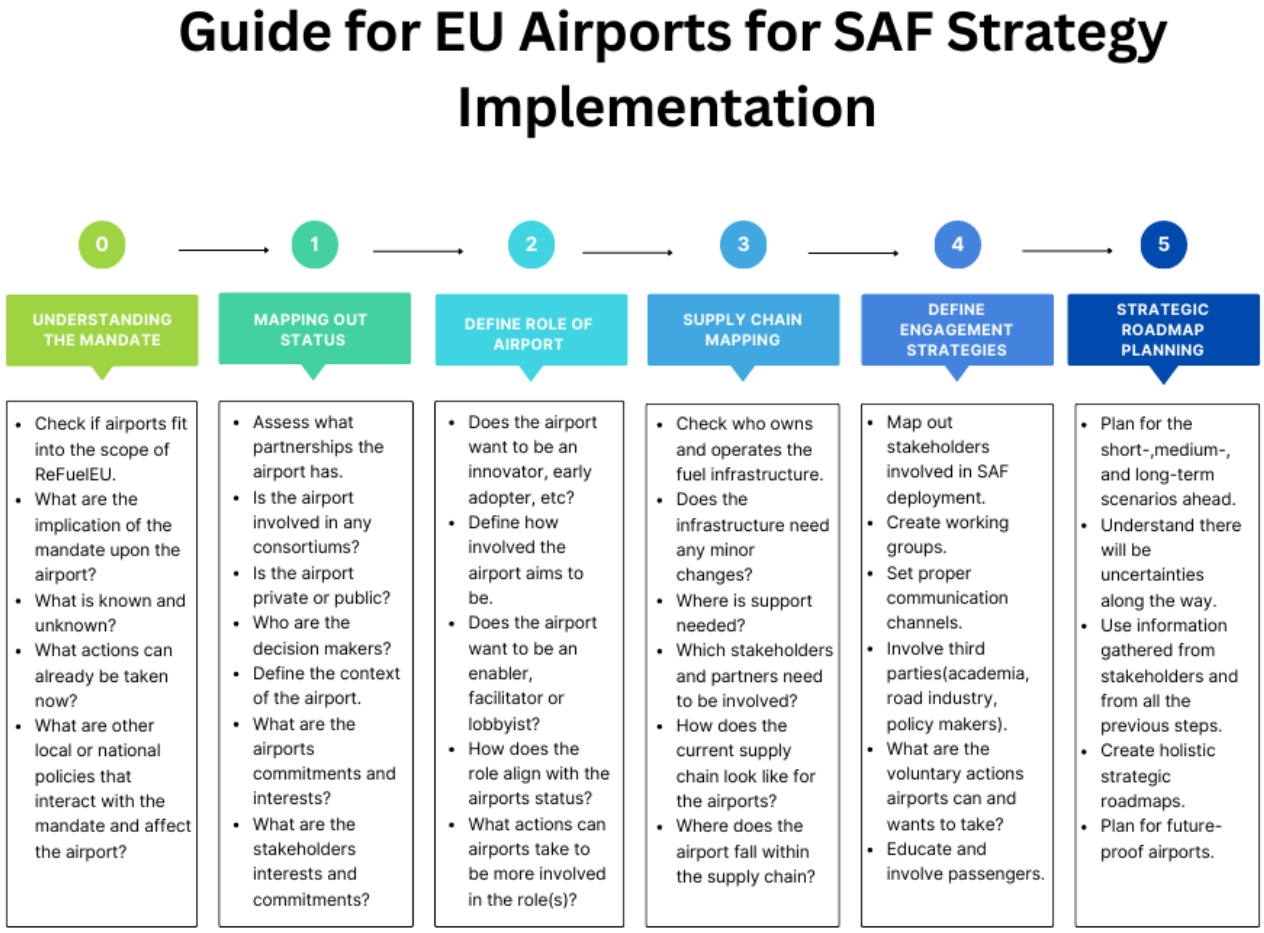


Figure 10: Guide for EU Airports for SAF Strategy Implementation.

questions that airports should focus on to meet the goal. The goals of each step shown in the figure are briefly described below. This guide, together with the actions and questions posed in each step provides a general overview of how airports can move forward considering the RefuelEU mandate and the increasing interest in SAF. The guide also aids NACO as a consultancy, to show its clients on which areas they can aid them in moving forward and provide them with advice and roadmaps needed for each step of the guide.

Description of the guide & its steps

0. Understanding the mandate: Before any of the steps are taken, the first action to be done is to understand the ReFuelEU mandate. Understand the general goals, the timeline, the direct and indirect impacts to airports, and the obligations required from airports. The following questions should be asked:
    a. Does the airport fall into the scope of ReFuelEU?
    b. What are the implications of the mandate on the airport and its operations?
    c. What is unknown and known?
    d. What is unclear and what questions arising from the mandate?
    e. Are there other local or national policies that interact with the mandate? Do these affect the airport?

1. Mapping out status: Assess and define the context of the airport and its surrounding environment, understand who makes the decisions within the airport, and what interest the airport has. Understand the political and organizational environment the airport is in, mapping out partners and direct shareholders. The following aspects and questions should be asked:
    a. Who are the decision makers and what does the decision-making process look like?
    b. What are the interests and commitments of the airports in relation to SAF & and sustainability? What are the interests of stakeholders/shareholders?
    c. Check if the airport has any partnerships and involvements with consortiums that are relevant to the uptake of SAF.
    d. Is the airport private or publicly owned?
    e. What are the contextual advantages and disadvantages?
    f. Look back at historical actions, has the airport received any batch of SAF or taken part of any demonstrations?
2. Define role of the airport: Once the context is defined, airports can choose what role they want to take or how proactive they aim to be. Depending on the airports' capabilities and interests' airports can assess what role or roles suits them best. The following considerations should be made:
    a. What do they aim to do and what role do they want to take up?
    b. Does the airport want to innovate, become an early adopter, facilitate, enable, etc.?
    c. How involved does the airport want to be? What actions does the airport need to take to be more involved or take upon the chosen role?
    d. Understand and study the roles (skills, capabilities, etc.).
    e. How does the role align and interact with the airport's status and interests?
3. Supply chain mapping: Understand the current supply chain of fuel and SAF in the airport. Map out the current supply chain and understand where the airport falls within the supply chain, comprehending the responsibilities and obligations that fall within the scope of the airport. The following questions should be answered:
    a. Who owns the fuel infrastructure? Are there any changes need to be made for the introduction of SAF? Where is support needed?
    b. What is the impact on airport operations and physical infrastructure for SAF implementation in accordance with the mandate?
    c. Which stakeholders and partners need to be involved?
    d. Who connects the stakeholders?
4. Define engagement strategies: Once the entire context of the airport is understood, the role defined and the supply chain is understood, airports can dive into engagement strategy definition. The following considerations must be made:
    a. Map out the stakeholders involved in the SAF deployment.
    b. Create working groups with stakeholders and understand their needs and interests. Do interests align with those of the airport? How can they favour each other?
    c. Create proper communication channels, considering the different stakeholders and their preferences.
    d. Involve third parties, such as academia, policymakers, and innovation management practices. Educate and involve passengers in the process.
    e. What voluntary actions do airports want to take and how does this help stakeholders?

5. Strategic roadmap planning: Lastly, as airports understand their positioning, role, and targets they aim to achieve strategic roadmaps can be created. Looking at best practices and information available airports can make advancements in the future, considering the ReFuelEU mandate. Additionally, consider interactions with other policies or targets that might hinder or facilitate sustainable innovations such as SAF.
    a. Plan for short-, medium- and long-term scenarios. Consider alternative scenarios, such as a no growth scenario (limits to growth).
    b. Understand uncertainties and barriers along the way.
    c. Ensure information gathered from the previous steps is included and evaluate them with stakeholders.
    d. Create holistic strategic roadmaps and plan for future proof airports (airports as energy hubs or adaptable).

7. Discussion

This research provides an insight on what the airports role could be in the diffusion and uptake of SAF. The gathered information and output from the research shed light on the fact that there are multiple uncertainties within the industry and the upcoming ReFuelEU mandate; not only airports are struggling to find their place within the mandate, but the other stakeholders affected by the mandate (airlines and fuel suppliers) have multiple questions for the future. The research touches upon the concept and theory of innovation in the context of airports and SAF, some of the literature reviewed suggests innovation management and engaging with different partners (academic sector and specialists on innovation) to successfully implement innovations within the industry. Additional research and analysis should be conducted on this, investigating airports and innovations aspects in details.

The literature, the interviews, and the attendance at the SAF congress revealed there is a slight disconnect between practices and recommendations, which was found by conducting the analyses of the methods. Literature has shown there is enough information on strategies that airports could choose to implement for the diffusion of SAF, nevertheless, the interviews and the congress showed that the system is more complex, and implementing strategies for SAF diffusion and uptake is more complicated. Even more so when there are multiple stakeholders involved in the decision-making process of the airport, and when the context and interests of the airport do not favor SAF diffusion or any other innovation.

From the interviews, it is not fully clear what are the differences, advantages or challenges the different airports might face if the airport is public or privately owned. Therefore, additional research into how each of these is affected should be investigated; and what the specific differences are of these two types of airports when it comes to innovation implementation and offering incentives. This could also affect the decision-making process on which strategies the airports could implement. Additionally, the size and location of airports might come into play on if it might be an advantage or disadvantage, therefore this should be investigated. Moreover, from the interviews some mentioned that airports should explore improving public transport connectivity and collaborate with other sectors such as the road transport industry. Industries that have used biofuels for a longer period, might give insight to airports on how their role could further develop in the long-term. It is recommended for airports to look into the improvement on road transport connectivity such as trains and buses could not only reduce their scope 3 emissions, local air quality and nose pollution but promote the usage of them instead of short haul flight for example.

The gathered and analysed information available online and from the attendance to the SAF congress, it was noted that airports, airlines, and fuel suppliers are overall not planning for a future scenario in which growth is limited or even decreases. This was further highlighted and mentioned by Matteo Mirolo during one of the panels at the SAF congress, realistically there must be a limit to growth, it is crucial for airports and other stakeholders to plan for a scenario in which this is the case. Therefore, it is recommended to seek advice on scenario planning on limited or decrease of growth in the future. Currently, many airports are planning for expansions and growth, to a certain extent some of these expansions are needed due to airports reaching its maximum capacity on passengers, nevertheless it is advisable to think on the future landscape, such as policies preventing short haul flights, private jets (an example is the recent developments in France for short haul flights and the Netherlands for private jets), or even the

increase on ticket prices. These factors and many more could have an impact on airports growth plan.

There are several feedstock uncertainties, which do not concern airports directly, however in the long run it might impact their current operations. This involves the conversion technologies being used to produce SAF and the feedstock for it, currently the primary method used is HEFA, however as the mandated amount of SAF increases every year HEFA will not be able to meet such demand. Therefore, it is projected FT and PtL will take over, nevertheless it is unclear how this shift of the conversion will occur or what will happen in between the transition from HEFA to FT/PtL, research is required into the conversion pathways, how the transition from each pathway will occur and how this affects airports and aircraft operations. Further research into the interaction of the industries of road transport and aviation, looking at the competition of feedstocks between them, potential collaborations, and future rollout to meet both goals and mandates for the industry.

Additional research is needed on the specific infrastructural changes for not only SAF as a blend in but as 100% SAF, infrastructures change for hydrogen, fuels and electric flights at airports and what airports must do specifically. Another relevant aspect that needs to be looked at are the costs related to the infrastructural changes at airports, how this will affect them directly, same for the airlines, airplane tickets costs, and fuel supply value chains. SAF should be used and viewed as a bridge to future technologies (hydrogen, electric), not as the sole solution. While SAF implementation strategies are going on, investments and advancements on other technological solutions should be considered together with strategic planning for future scenarios. Furthermore, during the interviews and the SAF Congress, the concept of airports as energy hubs was brough up several times. Airports have the potential in becoming energy hubs; their infrastructure, and multi-stakeholder players could benefit from this. Implementing renewables for energy could improve airports' road to decarbonization, airports as energy hubs should be further explored, including SAF and other technologies in such planning.

There is sufficient information, case studies and news pieces on airports who have successfully implemented SAF uptake mechanisms, there are several sources that give advice and recommendations on airports roles due to the limited time available for the research, only a few were reviewed and included in this research. Still a question that remains unanswered and should be investigated, why are airports not using the information, advice and recommendation that is available to them and why is there a large gap between the available information and the practice?

8. Conclusions

The information gathered and analysed does not allow to directly answer the research question posed at the beginning of this research. Revisiting the research question, *"What strategies can European airports implement to aid in the achievement of the ReFuelEU mandate up to 2050?"* and considering the complex nature and uncertainties airports and the industry face, no straightforward strategies can be given. As mentioned in the results, each airport must consider its own context and capabilities before trying to implement any strategies, they must decide how they want to position themselves, and to what extent they want to be involved within the ReFuelEU mandate. Instead of presenting a variety of strategies that could be implemented, this research provided a guide to help airports ask the right questions, which could lead to implementation strategies or the creation of strategic roadmaps with the information provided here.

The research shows that airports should play the role of facilitator and enabler in the uptake of SAF, this means their primary role will be to help fuel suppliers and airlines connect and collaborate with each other to achieve better outcomes. Additionally, airports should be more proactive in the lobbying and advocating process for SAF; such roles can be powerful and influential when it comes to supporting SAF uptake and diffusion. Their positioning in the industry can be advantageous to advocate and lobby for policies that contribute to the deployment of SAF as they could either hinder or promote the diffusion of SAF. Historically airports have played a more neutral role in the uptake of innovations within the industry, this includes the usage of SAF. Nevertheless, this role can be used to their advantage; the industry is highly competitive but the common goal for the decarbonization of the industry calls for close collaboration between other airports, airlines, fuel suppliers, policy makers, governments, and NGO's. Airports could be seen as good drivers of this conversation and give a pull to the industry and the market.

The introduction of the ReFuelEU mandate as it has been presented so far, does not pose any obligations and short-term challenges to airports. As found in this research, no immediate short-term actions regarding infrastructure changes at airports must be made, SAF as a drop-in fuel can be safely used in current fuel systems at airports. This could change in the future with the development of other technologies, aircraft and blending portions. Nevertheless, such infrastructural changes or adaptations might not fall into the airport's responsibilities, as many do not own or operate the fuel infrastructure. Even though there are no immediate actions that airports should be taking in face of the ReFuelEU mandate, they should understand it. Moreover, airports should be aware if they fall within the scope of the mandate; airports should be able to map out their own context and aid in the mapping of the supply chain, supporting and facilitating the other stakeholders on having an inventory on the fuel infrastructure and engaging with them.

The mandate brings many unknows to the aviation industry, airports are still trying to figure out what their role will be in the long term. The European Commission has still to specify several details, not only fuel suppliers and airlines, but also on the specific obligations and expectations for airports in the short- and long-term. It is a crucial time for airports to use their unique position in the supply chain to drive conversation and collaboration between all partners, including airlines and fuel suppliers. Collaboration and knowledge sharing between all stakeholders, different industries and among airports is key to achieve the ambitious goals on SAF and decarbonization, as it is a common goal in the ongoing battle against climate change.

References

ACI EUROPE. (n.d.). *Airports Council International Europe | ACI EUROPE - About us*. Retrieved April 5, 2023, from https://www.aci-europe.org/about/about-us.html

ACI Europe. (2022, June). *Guidance on Airports' Contribution to Net Zero Aviation*. https://www.aci-europe.org/downloads/content/Guidance%20on%20Airports%20Contribution%20to%20Net%20Zero%20Aviation.pdf

ACI World. (2021). *Sustainability Strategy for Airports Worldwide*. https://store.aci.aero/product/sustainability-strategy-for-airports-worldwide/

Ahlgren, L. (2022, May 11). *The Airports Leading The SAF Revolution*. https://simpleflying.com/leading-saf-airports/

Air bp. (2022, May). *Logistical considerations when introducing SAF mandates* . https://www.bp.com/en/global/air-bp/news-and-views/views/logistical_considerations_when_introducing_saf_mandates.html

Airbus. (2021, July 15). *Power-to-Liquids*. https://www.airbus.com/en/newsroom/news/2021-07-power-to-liquids-explained

Airlines for America. (2018, January). *Jet Fuel: From Well to Wing*. https://www.airlines.org/wp-content/uploads/2018/01/jet-fuel-1.pdf

AirportWatch. (2015, October 29). *Solena, the company meant to be producing jet fuel from London waste for BA, goes bankrupt*. https://www.airportwatch.org.uk/2015/10/solena-the-company-meant-to-be-producing-jet-fuel-from-london-waste-for-ba-goes-bankrupt/

ALIGHT. (n.d.). *ALIGHT - Sustainable Aviation*. Retrieved August 4, 2023, from https://alight-aviation.eu/

ATAG. (2017, November). *Beginner's Guide to Sustainable Aviation Fuel*. https://aviationbenefits.org/media/166152/beginners-guide-to-saf_web.pdf

ATAG. (2020). *Powering global economic growth, employment, trade, links, tourism and support for sustainable development through air transport, despite global crisis*. https://aviationbenefits.org/media/167517/aw-oct-final-atag_abbb-2020-publication-digital.pdf

ATAG. (2021). *Waypoint 2050: Balancing growth in connectivity with a comprehensive global air transport response to the climate emergency: a vision of net-zero aviation by mid-century*. https://aviationbenefits.org/media/167417/w2050_v2021_27sept_full.pdf

Baldanza, B. (2023, March 20). *The Aviation Industry Is Investing In Sustainable Fuel, But More Is Needed*. https://www.forbes.com/sites/benbaldanza/2023/03/20/the-aviation-industry-is-investing-in-sustainable-fuel-but-more-is-needed/

Bauen, A., Cesarek, T., Ticehurst, P., Abrams, L., & Speld, R. J. (2023, June 8). Personal Notes - Europe's 2023 Sustainable Aviation Fuels landscape: Projects, pricing & policies. *Sustainable Aviation Futures Congress, Amsterdam*.

Boeing. (2008, September). *Sustainable Aviation Fuel Users Group Our Commitment to Sustainable Options*. https://www.boeing.com/aboutus/environment/environmental_report_09/_inc/3.4.3-Sustainable-Aviation-Fuel-Users-group.pdf

Borodin, V., & Barbarà, L. (2023, June 26). *5 executives see airports as key to aviation decarbonisation*. https://www.weforum.org/agenda/2023/06/why-these-5-executives-believe-airports-are-the-key-to-aviation-decarbonisation/

Carlson, K. (2021, June 7). *Airport innovations take off*. https://aecom.com/without-limits/article/airport-innovations-take-off/

Council of the EU. (2022, June 2). *Fit for 55 package: Council adopts its position on three texts relating to the transport sector*. https://www.consilium.europa.eu/en/press/press-releases/2022/06/02/fit-for-55-package-council-adopts-its-position-on-three-texts-relating-to-the-transport-sector/

Covrig, A., Tedeschi, A., Jacobsen, J., Verreydt, C., Anamaterou, E., & Kroesen, F. (2023, June 8). Personal Notes - The Net Zero Roadmap for airports: Assessing and managing Scope 1,2 and 3 emissions. *Sustainable Aviation Futures Congress, Amsterdam*.

de Haas, V., Candela, J., Davis, E., Anderson, H., & Loken, A. (2023, June 8). Personal Notes - Airports and SAF: Developing effective supply chain, blending and logistics capabilities. *Sustainable Aviation Futures Congress, Amsterdam*.

De Haes, V. (2022, October 12). *Airports & Alternative Fuels Infrastructure in Italy*. https://to70.com/airports-alternative-fuels-infrastructure-in-italy/

de Haes, V., Tjaden, Q., Solanti, E., Woeldgen, E., Maharjan, S., & Malina, Prof. R. (2022). *Stargate Catalogue of Airport SAF Actions by Brussels Airport*. Stargate within EU Green Deal. https://issuu.com/brusselsairport/docs/saf_catalogue_for_airports_-_stargate/6?ff

de Jong, S., van Stralen, J., Londo, M., Hoefnagels, R., Faaij, A., & Junginger, M. (2018). Renewable jet fuel supply scenarios in the European Union in 2021–2030 in the context of proposed biofuel policy and competing biomass demand. *GCB Bioenergy*, *10*(9), 661–682. https://doi.org/10.1111/GCBB.12525

Destination 2050. (n.d.). *About Us - Destination 2050*. Retrieved April 20, 2023, from https://www.destination2050.eu/about-us/

EASA. (n.d.). *Sustainable Aviation Fuel* . Retrieved April 12, 2023, from https://www.easa.europa.eu/en/light/topics/sustainable-aviation-fuel

EASA. (2021). *Fit for 55 and ReFuelEU Aviation* |. https://www.easa.europa.eu/en/light/topics/fit-55-and-refueleu-aviation

EASA. (2022a). *EUROPEAN AVIATION ENVIRONMENTAL REPORT 2022*. https://www.easa.europa.eu/eco/sites/default/files/2023-02/230217_EASA%20EAER%202022.pdf

EASA. (2022b). *What are Sustainable Aviation Fuels?* . https://www.easa.europa.eu/eco/eaer/topics/sustainable-aviation-fuels/what-are-sustainable-aviation-fuels

Ellerbeck, S. (2022, December 9). *Can the aviation sector get to net-zero emissions by 2050?* . https://www.weforum.org/agenda/2022/12/aviation-net-zero-emissions/

Enright, C. (2011). *D7566 Takes Flight*. https://sn.astm.org/features/d7566-takes-flight-so11.html

EUROCONTROL. (2019, September). *Think Paper 4: The aviation network – Decarbonisation issues*. https://www.eurocontrol.int/sites/default/files/2020-01/eurocontrol-think-paper-4-decarbonisation-en.pdf

EUROCONTROL. (2021, June 8). *Data Snapshot #11 on regulation and focused logistics unlocking the availability of sustainable aviation fuels (SAF)*. https://www.eurocontrol.int/publication/eurocontrol-data-snapshot-11-saf-airports

EUROCONTROL. (2022, November 17). *Sustainable aviation fuels (SAF) in Europe: EUROCONTROL and ECAC cooperate on SAF map | EUROCONTROL*. https://www.eurocontrol.int/article/sustainable-aviation-fuels-saf-europe-eurocontrol-and-ecac-cooperate-saf-map

EUROCONTROL. (2023, March 7). *Aviation as a critical infrastructure: challenges and opportunities for a more resilient sector | EUROCONTROL*. https://www.eurocontrol.int/article/aviation-critical-infrastructure-challenges-and-opportunities-more-resilient-sector

European Commission. (n.d.). *Reducing emissions from aviation*. Retrieved April 11, 2023, from https://climate.ec.europa.eu/eu-action/transport-emissions/reducing-emissions-aviation_en

European Commission. (2021a, July 14). *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ensuring a level playing field for sustainable air transport*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0561

European Commission. (2021b, July 14). *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ensuring a level playing field for sustainable air transport*. https://eur-lex.europa.eu/resource.html?uri=cellar:00c59688-e577-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF#page=24

European Commission. (2023a, March 28). *New law agreed to deploy alternative fuels infrastructure*. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1867

European Commission. (2023b, April 26). *European Green Deal: new law agreed to cut aviation emissions by promoting sustainable aviation fuels*. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2389

European Parliament. (2022a, May 30). *ReFuelEU Aviation initiative: Summary of the Commission proposal and the Parliament's draft committee report* . https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)729457

European Parliament. (2022b, December 8). *ReFuelEU Aviation initiative: Sustainable aviation fuels and the fit for 55 package*. https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)698900

European Parliament. (2023, April 25). *Fit for 55: Parliament and Council reach deal on greener aviation fuels* . https://www.europarl.europa.eu/news/en/press-room/20230424IPR82023/fit-for-55-parliament-and-council-reach-deal-on-greener-aviation-fuels

Faber, J., Király, J., Lee, D., & Bethan, O. (2022). *Potential for reducing aviation non-CO 2 emissions through cleaner jet fuel*. www.cedelft.eu

Forster, P., Driessen, C., McClean, B., & du Preez, W. (2023, June 8). Personal Notes - Airport masterplanning & future fuel infrastructure: What planning is required to keep pace with sustainability & infrastructure changes in the airline industry? . *Sustainable Aviation Futures Congress, Amsterdam*.

Gelles, D. (2023, February 21). *A Sudden Rush to Make Sustainable Aviation Fuel Mainstream*. https://www.nytimes.com/2023/02/21/climate/united-sustainable-aviation-fuel.html

Graver, B., Zheng, X. S., Rutherford, D., Mukhopadhaya, J., & Pronk, E. (2022). VISION 2050 ALIGNING AVIATION WITH THE PARIS AGREEMENT. *ICCT*. www.theicct.org

Green Car Congress. (2020, May 14). *ASTM approves 7th annex to D7566 sustainable jet fuel specification: HC-HEFA* . https://www.greencarcongress.com/2020/05/20200514-ihi.html

Greer, F., Rakas, J., & Horvath, A. (2020). Airports and environmental sustainability: a comprehensive review. *Environmental Research Letters*, *15*(10), 103007. https://doi.org/10.1088/1748-9326/ABB42A

Hayward, J. (2022, March 6). *How Is Sustainable Aviation Fuel Created?* https://simpleflying.com/how-is-sustainable-aviation-fuel-created/

Honeywell. (2022). *Preparing for Liftoff: A Timeline of Sustainable Aviation Fuel (SAF) Milestones*. https://pmt.honeywell.com/content/dam/pmt/en/documents/document-lists/infographics/timeline-of-sustainable-aviation-fuel-milestones-infographic.pdf

IATA. (n.d.). *Developing Sustainable Aviation Fuel (SAF)*. Retrieved April 12, 2023, from https://www.iata.org/en/programs/environment/sustainable-aviation-fuels/

IATA. (2021a, December 1). *2050: Net-zero carbon emissions* . ENVIRONMENT. https://airlines.iata.org/analysis/2050-net-zero-carbon-emissions

IATA. (2021b, December 1). *2050: Net-zero carbon emissions | Airlines.* https://airlines.iata.org/analysis/2050-net-zero-carbon-emissions

IATA. (2022a). *Global Outlook for Air Transport Sustained Recovery Amidst Strong Headwinds*. https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport---december-2022/

IATA. (2022b). *Fact Sheet: EU and US policy approaches to advance SAF production*. https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/fact-sheet---us-and-eu-saf-policies.pdf

IATA. (2023a). *CORSIA*. https://www.iata.org/en/programs/environment/corsia/

IATA. (2023b). *Net zero 2050: sustainable aviation fuels*. https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---alternative-fuels/

IATA. (2023c). *What is SAF?* https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-what-is-saf.pdf

IATA. (2023d, April 26). *Statement on Refuel EU Proposals*. https://www.iata.org/en/pressroom/2023-releases/2023-04-26-02/

ICAO. (n.d.-a). *Facts and Figures*. Retrieved March 10, 2023, from https://www.icao.int/sustainability/pages/facts-figures_worldeconomydata.aspx

ICAO. (n.d.-b). *Sustainable Aviation Fuel (SAF)*. Retrieved April 12, 2023, from https://www.icao.int/environmental-protection/pages/SAF.aspx

ICAO. (2008, September). *Sustainable Aviation Fuel User Group (SAFUG)*. https://www.icao.int/environmental-protection/GFAAF/Pages/Project.aspx?ProjectID=13

ICAO. (2017). *Sustainable Aviation Fuels Guide*. https://www.icao.int/environmental-protection/knowledge-sharing/Docs/Sustainable%20Aviation%20Fuels%20Guide_vf.pdf

ICAO. (2022a). *REPORT ON THE FEASIBILITY OF A LONG-TERM ASPIRATIONAL GOAL (LTAG) FOR INTERNATIONAL CIVIL AVIATION CO2 EMISSION REDUCTIONS ICAO COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION (CAEP)*. https://www.icao.int/environmental-protection/LTAG/Documents/REPORT%20ON%20THE%20FEASIBILITY%20OF%20A%20LONG-TERM%20ASPIRATIONAL%20GOAL_en.pdf

ICAO. (2022b, November 10). *ICAO advocates for decarbonization of aviation at COP 27*. https://www.icao.int/Newsroom/Pages/ICAO-advocates-for-decarbonization-of-aviation-at-COP-27.aspx

Institut Montaigne. (2022). *Decarbonizing Aviation: All Aboard*. https://www.institutmontaigne.org/ressources/pdfs/publications/report-decarbonizing-aviation-all-aboard.pdf

Johnsson, M. (2018). The innovation facilitator: characteristics and importance for innovation teams. *Journal of Innovation Management JIM*, *6*, 12–44. https://www.diva-portal.org/smash/get/diva2:1238414/FULLTEXT01.pdf

Keszei, A., Hannifin, K., Nau, M., van Wijngaarden, L., Lopezbarrena, S., & Edmond, P. (2023, June 8). Personal Notes - Airline perspectives and sustainability levers: Evaluating SAF, operational efficiencies and new technologies to hit decarbonisation targets. *Sustainable Aviation Futures Congress, Amsterdam*.

Kiliç, S., Ucler, C., & Martin-Domingo, L. (2021). *Innovation at Airports: A Systematic Literature Review (2000–2019)*. https://doi.org/10.3846/aviation.2021.14917

López de la Osa, C. (2022, April 14). *Aviation policy alert: non-CO2 emissions have up to four times the climate impact* . https://energypost.eu/aviation-policy-alert-non-co2-emissions-have-up-to-four-times-the-climate-impact/

Malicier, V. (2021, November 11). *Fuel suppliers urge governments to impose SAF blending mandates*. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/111121-fuel-suppliers-urge-governments-to-impose-saf-blending-mandates

Martinez-Valencia, L., Garcia-Perez, M., & Wolcott, M. P. (2021). Supply chain configuration of sustainable aviation fuel: Review, challenges, and pathways for including environmental and social benefits. *Renewable and Sustainable Energy Reviews*, *152*, 111680. https://doi.org/10.1016/J.RSER.2021.111680

Mitchell, A. (2023, August 2). *The EU's SAF Blending Mandates: Everything You Need To Know*. https://simpleflying.com/eu-saf-blending-mandates-complete-guide/

Moore, G. A. (2014). *Crossing the Chasm:Marketing and Selling Disruptive Products to Mainstream Customers* (3rd ed.). HarperCollins. https://archive.org/details/crossingthechasm_202002/page/n73/mode/2up

NLR, & Destination 2050. (2021, February). *Destination 2050-A route to net zero European Aviation* . https://www.destination2050.eu/wp-content/uploads/2021/03/Destination2050_Report.pdf

OLGA. (n.d.). *OLGA | hOListic Green Airport*. Retrieved August 4, 2023, from https://www.olga-project.eu/

Opare Mintah, E. (2023, April 14). *Do airports deserve a bad reputation on sustainability?* https://www.internationalairportreview.com/article/184138/do-airports-deserve-a-bad-reputation-on-sustainability/

Pardoe, J. (2022, September 22). Understanding the pathways, policies, economics, and business case for SAF [PowerPoint slides]. *Sustainable Aviation Futures, SAF Masterclass*.

Pilling, M. (2021, March 25). *How sustainable fuel will help power aviation's green revolution*. https://www.flightglobal.com/flight-international/how-sustainable-fuel-will-help-power-aviations-green-revolution/143044.article?adredir=1

RBS. (2022). *SAF Sustainability Guidance for Airports*. https://rsb.org/wp-content/uploads/2023/01/SAP-2022-SAF-Guidance-for-Airports.pdf

Ritchie, H. (2020, October 22). *Climate change and flying: what share of global CO2 emissions come from aviation? - Our World in Data*. https://ourworldindata.org/co2-emissions-from-aviation

Rogers, E. M. (1983). *Diffusion of Innovation* (3rd ed.). Collier Macmillan Canada. https://teddykw2.files.wordpress.com/2012/07/everett-m-rogers-diffusion-of-innovations.pdf

RSB. (2023, April 5). *RSB Book & Claim Manual set to accelerate aviation decarbonisation - RSB*. https://rsb.org/2023/04/05/rsb-book-claim-manual-set-to-accelerate-aviation-decarbonisation/

Santos, K., & Delina, L. (2021). Soaring sustainably: Promoting the uptake of sustainable aviation fuels during and post-pandemic. *Energy Research & Social Science*, *77*, 102074. https://doi.org/10.1016/J.ERSS.2021.102074

Schafer, A., Abera Abate, M., & Schlumberger, C. E. (2022, October 27). *Decarbonizing air transport: Sustainable aviation fuels are vital for growth*. https://blogs.worldbank.org/transport/decarbonizing-air-transport-sustainable-aviation-fuels-are-vital-growth

Sinusoid, D. (2021, October 16). *How to Measure Technological Maturity*. https://www.shortform.com/blog/technological-maturity/

Soone, J. (2020). Sustainable aviation fuels. *European Parliamentary Research Service*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/659361/EPRS_BRI(2020)659361_EN.pdf

Soone, J. (2022, May 31). *ReFuelEU Aviation initiative: Summary of the Commission proposal and the Parliament's draft committee report* . https://epthinktank.eu/2022/05/31/refueleu-aviation-initiative-summary-of-the-commission-proposal-and-the-parliaments-draft-committee-report/

Soone, J. (2023). ReFuelEU Aviation initiative: Summary of Parliament's and Council's positions. *EPRS | European Parliamentary Research Service*. https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/739347/EPRS_BRI(2023)739347_EN.pdf

Stargate. (n.d.). *Green Deal Stargate*. Retrieved August 4, 2023, from https://www.greendealstargate.eu/

Surgenor, C. (2023, February 22). *Heathrow offers airlines £38m to support greater use of SAF as government consults on 2040 zero-emission target for airports* . https://www.greenairnews.com/?p=3971

Sustainable Aviation Futures Congress. (2023). *Sustainable Aviation Futures Europe*. https://www.safcongress.com/

Su-ungkavatin, P., Tiruta-Barna, L., & Hamelin, L. (2023). Biofuels, electrofuels, electric or hydrogen?: A review of current and emerging sustainable aviation systems. *Progress in Energy and Combustion Science*, *96*, 101073. https://doi.org/10.1016/J.PECS.2023.101073

Tegan, G. (2022, January 27). *Semi-Structured Interview* . https://www.scribbr.com/methodology/semi-structured-interview/

Tidey, A., & Wright, R. (2023, May 2). *More sustainable fuels, less "tankering": How new EU rules aim to cut aviation's enormous emissions | Euronews*. https://www.euronews.com/my-europe/2023/04/26/heres-how-the-eu-wants-to-make-your-flight-greener

Transport & Environment. (2016). *Aviation emissions and the Paris Agreement Europe and ICAO must ensure aviation makes a fair contribution to the Paris Agreement's goals*. http://unfccc.int/resource/docs/2014/sbi/eng/20.pdf

Transport & Environment. (2022, January 31). *The good, bad and the ugly of SAF mandates*. https://www.transportenvironment.org/discover/the-good-bad-and-the-ugly-of-saf-mandates/

TULIPS. (n.d.). *The TULIPS Consortium*. Retrieved August 4, 2023, from https://tulips-greenairports.eu/

UNFCCC. (2015). *The Paris Agreement* . https://unfccc.int/process-and-meetings/the-paris-agreement

van Dyk, S. (2021, July 16). *European Commission's ReFuelEU Aviation proposal details SAF blending obligation on fuel suppliers*. https://www.greenairnews.com/?p=1374

van Dyk, S. (2022, February 1). *Sustainable aviation fuels are not all the same and regular commercial use of 100% SAF is more complex*. https://www.greenairnews.com/?p=2460

Viinikainen, M. (2022, December 1). Flash Talk: Sustainable Airport Operations. *EASA Annual Safety Conference*. https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=0CDcQw7AJahcKEwjQiNKTrIyBAxUAAAAAHQAAAAAQAw&url=https%3A%2F%2Fwww.easa.europa.eu%2Fen%2Fdownloads%2F137428%2Fen&psig=AOvVaw3I8W_8lJnuEaIRn7d8xIC2&ust=1693758474948596&opi=89978449

Vuckovic, I., & Puls, R. (2022). *Controlling, Guiding and Assisting: The Role of Airports in the Transition Towards Environmentally Sustainable Aviation*. 137–161. https://doi.org/10.1007/978-3-030-90895-9_7

Wesoff, E. (2017, April 19). *Hard Lessons From the Great Algae Biofuel Bubble*. https://www.greentechmedia.com/articles/read/lessons-from-the-great-algae-biofuel-bubble#gs.5jG2khs

Appendix I: Informed consent form

The following informed consent form has been taken from the Utrecht University platform and will be adapted for the interviews. The consent form is in line with the Universities privacy guidelines and requirements for interviews. University's

Informed consent form (interview)

In this study, we want to learn about Sustainable Aviation Fuel and its implications for airport infrastructure, planning, and general impacts. Participation in this interview is voluntary and you can quit the interview at any time without giving a reason and without penalty. Your answers to the questions will be shared with the research team. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act). Please respond to the questions honestly and feel free to say or write anything you like.

[Only in case of anonymous handling: Everything you say or write will be confidential, and anonymous. This means that we do not ask for your name, and no one will know which respondent said what.]

I confirm that:

- I am satisfied with the received information about the research;
- I have no further questions about the research at this moment;
- I had the opportunity to think carefully about participating in the study;
- I will give an honest answer to the questions asked.

I agree that:

- the data to be collected will be obtained and stored for scientific purposes;
- the collected, completely anonymous, research data can be shared and re-used by scientists to answer other research questions;

I understand that:

- I have the right to see the research report afterwards.

Do you agree to participate? o Yes o No

Information Sheet (interview)

Introduction

You are invited to take part in this study on Sustainable Aviation Fuels. The purpose of the study is to learn about XXX. The study is conducted by Helena Rodriguez who is a student in the Msc programme Sustianbale Develompent at the Department of Sustainable Development, Utrecht University. The study is supervised by Ric Hoefnagels

Participation

Your participation in this interview is completely voluntary. You can quit at any time without providing any reason and without any penalty. Your contribution to the study is very valuable to us and we greatly appreciate your time taken to complete this interview. We estimate that it will take approximately 30-35 minutes to complete the interview. The questions will be read out to you by the interviewer. Some of the questions require little time to complete, while other questions might need more careful consideration. Please feel free to skip questions you do not feel comfortable answering. You can also ask the interviewer to clarify or explain questions you find unclear before providing an answer. Your answers will be noted by the interviewer in an answer template. The data you provide will be used for writing a Master thesis report and may be used for other scientific purposes such as a publication in a scientific journal or presentation at academic conferences. Only patterns in the data will be reported through these outlets. Your individual responses will not be presented or published.

Data protection

The interview is also audio taped for transcription purposes. The audio recordings will be available to the Master student and academic supervisors. We will process your data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

[In case audio recordings will be deleted: Audio recordings will be deleted when data collection is finalized and all interviews have been transcribed.]

In case audio recordings will not be deleted: Audio recordings will only be stored on a secured and encrypted server of Utrecht University]

[In case of anonymous interview: Everything you say in this interview will be confidential and completely anonymous. This means that we will not ask for your name, date of birth, or other personal information that can be traced to you by us or a third party]. We will process your data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act)]

Appendix II: Interview Sample Questions

Interview Expert:

1. Could you tell me about what you worked in? (shortly, in relation to your expertise on SAF)
2. How does X view SAF?
3. Can you tell me something about the X plan of approach regarding SAF implementation and it's stated goals on SAF?
4. How do organizations such as X and the Y view SAF and the airports role in it?
5. How do you see airports playing a role in the diffusion or upscaling of SAF?
6. Would you consider airports to be a crucial actor in the diffusion of SAF?
7. What are the important aspects airports should consider when trying to implement SAF in their operations?
8. Where do you think airports place in the entire supply chain of SAF?
9. What actions do you think are necessary for airports to take on for SAF to be implemented?

Interview Fuel Supplier:

1. How does X view airports in the uptake of SAF?
2. What role do you think airports should play in the uptake and diffusion of SAF?
3. Without a stronger policy push from the government, what do you think airports can do to push the usage of SAF?
4. What infrastructure requirements do you think are needed in the long term for the uptake of SAF to meet the EU goals?
5. Do you consider these actions alone be enough to reach ReFuel EU targets?
6. How do you think airports can influence the availability of SAF?
7. How do you think SAF airport mandates will clash with EU mandates and what do you think will be the solution for this?
8. Airports are not involved in the fuel purchase process, however, they provide the infrastructure do you think airports could hold more power over what fuel airlines buy?
9. How can airports aid in the uptake of SAF without losing competition?
10. How can airports help avoid tankering?
11. How can airports avoid airline dissatisfaction and avoid them diverting to other airports?
12. Which incentives or strategies would you concede viable only for short-term? Medium-term and long-term?

Asset managers and stakeholders of airports

1. How do you perceive the role of airports in driving the uptake of Sustainable Aviation Fuel (SAF), and what impact do sustainable aviation practices have on airport assets?
2. What are the main challenges and opportunities you encounter when implementing SAF initiatives at airports?
3. How do you collaborate with airlines, fuel suppliers, and other stakeholders to promote and facilitate the use of SAF at airports?
4. How do you measure and track the environmental impact and benefits of implementing SAF at airports?
5. Are there any specific policies or regulations that affect the implementation of SAF initiatives at airports, and how do you navigate them?
6. What role does technology and innovation play in supporting the uptake of SAF at airports, and how do you leverage them?
7. Can you share any success stories or best practices of airports implementing SAF initiatives that you have been involved in or witnessed?
8. How do you envision the future of SAF implementation at airports from the perspective of asset managers/stakeholders? Are there any emerging trends or opportunities?
9. How do you collaborate with other airports and industry stakeholders?

Questions for academics

1. As an academic professor, what is your perspective on the role of airports in driving the uptake of Sustainable Aviation Fuel (SAF)?
2. What are some of the key challenges and opportunities airports face when implementing SAF initiatives?
3. How do you see the role of airports in influencing airlines and fuel suppliers to adopt and utilize SAF?
4. How can airports collaborate with academic institutions and researchers to enhance SAF implementation and address related challenges?
5. Are there any specific research areas or topics that you believe need further exploration to better understand the role of airports in SAF uptake?
6. In your opinion, what role does public perception and community engagement play in the successful implementation of SAF initiatives at airports?
7. that you believe airports can participate in to advance SAF implementation?
8. How do you envision the future of SAF implementation at airports, and what role can academic institutions play in supporting this transition?

Questions for airlines

1. Can you provide an overview of your airline's current initiatives and strategies related to sustainable aviation fuel (SAF) implementation?
2. How do you perceive the role of airports in driving the uptake of SAF for airlines, and what impact do airports have on your airline's sustainability goals?
3. What are the main challenges faced by airlines in implementing SAF initiatives at airports?
4. How do you collaborate with airports and fuel suppliers to ensure a reliable supply of SAF?
5. What role do airports play in influencing your airline's decision to adopt SAF? Are there any incentives or partnerships that encourage your airline's participation?
6. Are there any regulatory or policy requirements that airlines and airports need to consider when implementing SAF initiatives?
7. Are there any technological advancements or innovations that airports can implement to enhance the uptake of SAF for your airline?
8. From your perspective, what role do airports play in ensuring a reliable and consistent supply of SAF?
9. Can you share any success stories or best practices of airports actively promoting SAF adoption from your airline's point of view?
10. How do you envision collaboration between airlines and airports evolving in the future to further accelerate the uptake of SAF?.

Questions for the road transport sector on sustainable fuels

1. How has the road transport sector adapted to move into using more sustainable alternatives?
2. What is the road transport sector doing regarding biofuels? How is it being measured? How does the supply chain work?
3. What are the relevant stakeholders involved?
4. What strategies has the sector implemented that you think could be replicated into other sectors such as the aviation sector?
5. Do you think there will be increased competition between aviation and transport sector?
6. Do you think there should be some sort of collaboration between sectors?

Appendix III: Literature Review

Title	Author	Search word(s)	Key Findings	Main Advice and Outcomes
Catalogue of Airports SAF Actions: Actions for Airports to Stimulate the Uptake of Sustainable Aviation Fuel	(de Haes et al., 2022)	SAF airport actions	Three main action points: Increase SAF Uptake: Applying Authority & Financial Support Increase SAF awareness: Information Campaigns, Passenger Nudging & Publish Research Results Increase airport Leadership on SAF: Stakeholder Engagement & Align own organisation	The catalogue provides more than 25 actions for airports to select from to encourage the uptake of SAF. Airports should consider their local context to implement the actions mentioned in the catalogue. The most important actions for airports to take include: SAF incentives and funds, stakeholder coordination and setting up a stakeholder working group.
The Airports Leading The SAF Revolution	(Ahlgren, 2022)	SAF implementation at airports	Some airports are moving faster in ensuring they can obtain SAF supply for their operations and internal goals. Airlines operating at such airports will benefit from this, having access to SAF directly which can potentially lead SAF prices to go down at a faster rate. Airport actions: Norway airports: blending mandates were set (0.5% SAF to departing flights) Schiphol airport (Netherlands): Invested in the construction of Europe's first sustainable kerosene plant. KLM (leading airline at Schiphol) allows passengers to buy a portion of drop-in fuel by charging more for the flight ticket (KLM is adding 0.5% of SAF to all flights departing from AMS). London Heathrow: world's largest major airport SAF provider. Incentive program established for airlines and passengers (resulting in 0.5% SAF tanked at the airport). San Francisco International airport (SFO, USA): leading role in bringing SAF to not only domestic flights but international airlines. Part of lobbying coalition to expand on Low Carbon Fuel Standard (LCFS) which offers incentives on SAF. Enabled agreements between several airlines for increasing the use of SAF. Other airports: Port of Seattle developed a roadmap for transitioning all airlines operating at Seattle-Tacoma to fly 10% on SAF by 2028. Airlines are coming into agreements with airports committing to provide SAF blends in their operations.	Airports have a certain amount of power to lead in the implementation of SAF. Airports can organize the availability of SAF at their location. Airport stakeholders' investment in projects has an impact on growth and SAF implementation.

Soaring sustainably: Promoting the uptake of sustainable aviation fuels during and post-pandemic	(Santos & Delina, 2021)	Sustainable Aviation Fuel implementation strategies	For long-term SAF uptake changing airport infrastructure will be required: new pipelines in airports. Stakeholders in the aviation sector such as airports can create a push for governments to support the transition to SAF. Clean Skies for Tomorrow advice on governmental policy: Government-backed price floors at initial SAF production (encouraging investments from other sectors). Clear timeline for SAF blending mandate: EU clean energy skies coalition.: boost market confidence. Countries can star adapting blending mandates in short-haul flights (domestic or regional) Government incentives: example of USA system of Renewable Identification Number (RIN) Business-to-Business Incentives: Customers and corporations are looking for way to decrease their carbon footprint. Airlines or airports could partner with corporate customers who can afford and are willing to pay an extra price to decarbonize their business travels. Business-to-Consumer Incentives: Airlines can implement royalty programs to target and incentivize individual consumers to mitigate their emissions with SAF.	The uptake and promotion of SAF need multi-stakeholder partnerships between airports, airlines, governments, fuel producers, and investors. Incentive programs and strategies used for airlines can also be applied for airports.
Sustainable Aviation - Chapter: Controlling, Guiding and Assisting: The Role of Airports in the Transition Towards Environmentally Sustainable Aviation	(Vuckovic & Puls, 2022)	role of airports in sustainable aviation fuel	A big challenge for aviation to successfully transition to become more sustainable it requires all system members to do so as well. Airports are uniquely positioned to aid other system members on their path to reach sustainability. Airports can think of direct and indirect influences it can have on airlines and the aviation industry. Important to note airlines are worthless without the infrastructure airports provide to them. All components in the system must commit to transition to more sustainable operations. Airports should think about their future impact on the environment and the public pressure, considering climate protests and the legal actions surging from them. Airports should consider not only emissions committed by them but also at their location by other parties.	To achieve system changes in the aviation sector toward environmental sustainability, all system members must play a role. Airports have well-developed solutions to reduce their own Scope 1 and 2 GHG emission. Airports can use their unique context to implement action plans. Airports can be successful facilitators between airlines and fuel producers in the production of SAF. Airports could play 3 different roles: Controlling: This includes regulating, (dis)incentivizing, choice architecture and monitoring Guiding: Communicating, educating, signalling, and leading by example.

			Cost subsidies to airlines to purchase SAF. Multiple airports were interviewed and considered in the study to investigate strategies to reduce Scope 3 emissions. The study provides an Airport Sustainability Stakeholder Influencer Framework.	Assisting: Cooperating, enabling and supporting.
Innovation at airports: A systematic literature review (2000–2019)	(Kiliç et al., 2021)	Innovation at airports	No specific research on academia on how airport innovation can be achieved. The EU policy and initiatives (Horizon2020) have generated a significant amount of research on airport innovation. Airport design and planning is a complex process. Lack of collaboration between airport professional and researchers for the development of new products/services. Rising trend on innovation at airports. Collaboration with passengers is valuable and crucial for innovation. Companies mismanaging technologies and innovation might affect airports. Airports innovate on a few areas, namely they focus on product and service innovation, ICT leveraging, and they aim to implement some innovations without having a strategic approach to it. Airports are missing input and collaboration between innovation scholars and specialists,	Strategic planning at airports should involve bold innovations and targets. The innovations should be driven byu the technology and the market. Focus on marketing innovation for new products and services. Airports could adopt innovation management practices, such as other sectors (e.g., road transport sector. Airports should tie their innovation practices to specific products, processes, or services. Innovation scholars should enter the aviation sector or aviation scholars study innovations.
Heathrow offers airlines £38m to support greater use of SAF as government consults on 2040 zero-emission target for airports	(Surgenor, 2023)	Heathrow SAF incentives	Airport wants to lead in SAF. First airport to offer SAF contribution to airlines. 5 airlines participate in the SAF scheme set up. USA policy might lure SAF investors to USA, leaving the UK to miss out. Delay in action might cause local SAF industry lags and cannot keep up internationally. Airports do not control Scope 3 emissions but can influence them.	SAF competition between USA, UK, and Europe. Support mechanisms from the government is needed. Airport pushing government on SAF mandate and projects locally to keep up with international demand. NGOs and environmentalists consider Scope 3 emissions from airports should be more ambitious. Partnerships important to meet decarbonization roadmaps.
The innovation facilitator: characteristics and importance for innovation teams	(Johnsson, 2018)	Innovation facilitator	Facilitator: educates, advocates, and advises. Facilitators are crucial in the pre-phase of the innovation process. Facilitators support innovation and innovation teams.	Facilitator presence in innovations is crucial. Skills such as facilitating, coaching, teaching and group dynamics were crucial. Knowledge in innovation management is useful for facilitator roles.
A Sudden Rush to Make Sustainable Aviation Fuel Mainstream	(Gelles, 2023)	SAF mainstream	Increase on investments, policy changes and new technological innovations have boosted the market for SAF and alternative technologies.	Making SAF mainstream will be very costly and difficult. Main concern and issue are upscaling production and its

			Rising laws in Europe and USA are driving up the investments on the market. United airlines and Boeing are increasing their investments and usage of SAF. SAF seen as the most promising technology/innovation to reducing emissions from the industry. Almost no SAF is being used currently due to the high costs. There are only two major companies producing SAF used by only major airlines.	deployment considering the price and feedstock availability. Growth of SAF producer start-ups. Increase usage of carbon-offsets by airlines could be problematic.
Renewable jet fuel supply scenarios in the European Union in 2021–2030 in the context of proposed biofuel policy and competing biomass demand	(de Jong et al., 2018)	N/A	Competition for biomass feedstocks between different sectors: aviation, road chemical sector). Biofuel targets on other transport sectors play a role on how future scenarios for aviation will develop. The increase of renewable jet fuel using non-food biomass will have an impact on other sectors and the price of the biomass.	Growth of renewable jet fuels depend on the right policies and incentives provided. Research into local or regional production of renewable jet fuel is encouraged. Interactions between sectors using biomass should be considered in the long-term.
The Aviation Industry Is Investing In Sustainable Fuel, But More Is Needed	(Baldanza, 2023)	SAF investments	Industry of aviation built on fossil fuels, therefore decarbonization is extremely challenging. New aircrafts are built more efficiently. With enough SAF worldwide airlines could become carbon neutral. The rate SAF is produced compared to demand of the industry is slow. IATA projected and increased need for SAF to meet 2050 goals. SAF costs are not reflected in long-term strategies on sustainability. Fuel represents 30% of the cost structure of an airline. Replacement of aircrafts to more efficient ones is also required. Room for new technologies (hydrogen and electric) must be considered. IATA and other organizations should call major airlines and partners to increase sustainability initiatives.	Aviation companies and airline partnerships to increase SAF production. Airlines and fuel producer partnerships. Encouraging partnerships are crucial first steps to increase SAF production and uptake. Meaningful SAF production will not pe viable in the next 5 to 10 years. Infrastructure needed to produce SAF at high volumes will increase SAF costs by 50% to 100% compared to conventional jet fuel. SAF will likely play a smaller role than the current market expects. SAF shouldn’t be considered as the sole solution.
Sustainable Aviation Fuels Guide	(ICAO, 2017)	sustainable aviation fuels implementation	Stakeholders from the industry should engage with each other, sharing knowledge and resources. Diversification of SAF feedstocks could facilitate bringing SAF production closer to airports. Helping the ramp up of SAF. Non-drop-in SAF requires additional infrastructure to be implemented at airports, imposing extra higher costs. Focusing on logistics of developing a supply chain to aid airports to move past	Airports involved as stakeholder in developing and deploying SAF. Facilitate and follow quality control procedures at airports. Defining roles and responsibilities among stakeholders is crucial to foster SAF innovations. Understand the supply chain. In initial stages provide SAF at select airports to empower SAF expansion.

			demonstration flights and towards regular SAF distribution.	
Airport innovations take off.	(Carlson, 2021)	Airports, Innovation	Airport innovations are focused on safety, landscape, sustainability, planning, financing, and security. Public and passenger expectations on airports towards sustainability.	Airport innovation is essential for creating and operating smart next generation airports.
Guidance on Airports' Contribution to Net Zero Aviation	(ACI Europe, 2022)	Airports Net Zero	Airports have several reasons to support emission reductions from aircrafts and operations: link between stakeholders that can aid in concrete actions on the ground to support others. Airports receive most of the public criticism, since they are the most tangible stakeholder form the industry. Airport can attract leading airlines, aiming to decrease scope 3 emissions. Heathrow, Schiphol, Swedavia and Avinor have been able to provide incentives to airlines in relation to the uptake of SAF. Depending on the airports role they can choose to deliver or enable aircrafts towards decarbonization. Airports do not sell or purchase fuel, only a handful are involved with fuel distribution. Airports rarely own the fuel infrastructure on-site. They primarily provide the land for the fuel operator to own and manage the infrastructure. Blended SAF is treated the same was Jet A1 fuel.	Airports can take up the role of enablers: stakeholder engagement, advocacy with policy makers and communication with airlines and other stakeholders. Airports could also deliver, by providing infrastructure, investing in SAF, and related projects. The role an airport can take depends on their circumstances. Airports can explore what economic mechanisms they can implement to support low-carbon technologies and fuels. Airports should seek how to support SAF implementation. Enable: Engage with SAF producers and airlines (working groups and feasibility studies) Help the supply chain understand their role (customs requirements). Aid in establishing accounting and reporting mechanisms in accordance to which airline can claim the SAF. Educate passengers. Deliver: Invest in SAF storage tanks, blending facilities, and (local) production plants. If possible, cover additional SAF costs (Incentives).
Airports & Alternative Fuels Infrastructure in Italy	(De Haes, 2022)	Airport Rome sustainable fuel	Main fuel supplier delivering limited amount of SAF to some airports in Italy (Rome, Milan, and other airports). Airport in Torino testing electric flights. Bologna airport investing in multimodal airport access. Collaboration between stakeholders can deliver successful projects, develop synergies, and create consensus on the future of aviation.	Partnering with local fuel suppliers, governments and airlines. Investing in innovative technologies and projects. Provide incentives promoting sustainability. Airports should: Understand their current and future operations. Work together with governments. Develop future infrastructure. Create a business case for sustainability and SAF. Find synergies.

Sustainability Strategy for Airports Worldwide	(ACI World, 2021)	Sustainability at airports	Scope 3 emissions include emissions from aircrafts. Develop innovative business models. Electrification of ground operations. Assessing own business travel. Considering biofuels in airport roadmaps.	Partnering with airlines to explore logistics and infrastructural needs in the SAF supply chain. Defining their role in the supply chain. Help finance SAF and invest on SAF projects. Displaying own use of fossil fuels with renewable alternatives.

Appendix IV: Interview Transcription Summary Table

Stakeholder/expert categorization	Interviewees	Main Outcome & Relevant Information	Main Concerns, Challenges & Questions
Fuel Suppliers	SAF producer and distributer 1	Airports are an important stakeholder; however, they are not involved in the purchasing of the fuel. • Each airport organized their infrastructure differently, same for the access to the fuel supply. • Getting SAF to airports with Open access fuel infrastructure might be easier. • Some airports do not operate their own fuel supply infrastructure. • Many airports do not seem very active in promoting or being open to create access for SAF suppliers to the airport. • If airports have own ambitions towards SAF and sustainability they are more open • Airports can be more vocal, facilitators to the transitions. • Airports could provide incentives • No value on having blending facilities on site unless it becomes cheaper to do so in the future: multiple risks with blending on cite regarding fuel standards and safety. • Airports could have a bigger role in medium to long term • Airports could already be checking inventory and seeing what their infrastructure is able to do today and plan: changing infrastructure and doing maintenance takes time. • Airports will not have a strong role, unless they take a step beyond the mandate; airports are long term so they should be planning long-term staying ahead of mandates and sustainability aspects	Questions: • How will fuel suppliers fill their obligations per the mandate? • What is the definition of a supplier according to the mandate? • Can suppliers meet their SAF obligations at only one location? • What will happen when some aircrafts can use 100% SAF and other cannot in the same location? Challenges/concerns: • Airports not being open to help access infrastructure systems • A lot unclarity on what fuel suppliers must do or behave per the mandate • Costs of SAF compared to fossil fuels • SAF certifications and standards • Competition with other countries that already have SAF mandates in place for a long time and airports giving incentives • Penalties may play a role on where fuel suppliers decide to provide their SAF
	Multinational oil and gas company	Fuel suppliers might need to reorganize to meet mandated supply on SAF • Fuel supplier has spoken to airports • Airlines will buy SAF where it is cheaper. • Airports that have incentives for SAF, get more portions of SAF. • Countries with mandates already in place give incentives to further drive the price down. • Airports should not blend, there is high risk on ensuring the quality of the fuel • Leave fuel suppliers to deal with blending and outside infrastructural changes • Airports do not need specific infrastructure for blend in SAF	Questions: • How to get SAF to other locations (not only big hubs)? • How to avoid fraud with book & claim, mass balance, allocation of scope 3 emissions and other mechanisms? Challenges/concerns: • Solid Robust processes are needed end to end top meet obligations. • Limit how much airports can subsidize • Country-level organization is needed • Only a few airports will have SAF on location, many smaller airports might like to have it there.

		• Airlines shouldn't ask for physical SAF on their wing, it generates extra costs • Best practice example: airport in Scandinavia makes SAF blend mandatory, they only provide SAF blend fuel at the airport • Many incentives available: landing fee charges reduced, carrot or stick incentives • Collaboration needed between all parties in the industry, despite the competition. • Proactivity from airports with governments needed. They should move ahead or they will be lagging.	• Fraud, unsustainability and, greenwashing
	SAF producer and distributer 2	• SAF projects and plans take approximately 7 years in Europe. • Airports have limited roles in the supply chain. • Airports give out licenses to operate on the airport. However, many do not own the infrastructure. • Airports can play a role as an enabler and advocators. • SAF should be considered in business plans. • Open access fuel infrastructure and organization can help in the uptake of SAF (Hong Kong airport has such system). • Only a handful of airports taking the lead on SAF before mandate. • Taking the lead depends on the type of airports, if it is partly state owned or private, if the CEO or main stakeholders have interest on SAF. • Incentives on SAF by airports have proven to help. • Long-term 100% SAF flight will be available. • Airports should be involved in long-term planning • Net-zero might mean not expanding terminal. • Aligning ambitions with other partners (airlines and fuel companies). • Airports can improve connections with road and public transports. Making then intermodal transport hubs. • Airports as energy hubs.	Questions: • How will the transition of aircrafts will occur and what does this mean for infrastructural and organizational changes at airports? • What are the limits to growth as a company, airport, and airline? Challenges/concerns: • Risks on investments not paying off. • Access to the fuel infrastructure, which is usually owned by multiple partners. Oil majors usually own the infrastructure. • Airlines resisting fee changes when SAF is being implemented by the airport. • Safety and certification issues. • Infrastructural changes for 100% SAF and other technologies (hydrogen and electric). • Companies not considering the limit to growth. • Planning for growth and sustainability do not go together. • Underestimating the power of lobbying.
Airports & Airport Consortiums	Large airport in the Benelux area and related consortium 1	Airport and consortium looking into the stimulation of SAF uptake, hydrogen and electric. Every 5 years new discussions and negotiation on tariffs • Airport has advantage to be connected to a crucial pipeline which recently allowed the injection of SAF into pipeline. • Mandate falls mainly under fuel suppliers' responsibility, no specific or clear obligations on the airport.	Questions: • What is the role of the airport in the mandate? • How will mass balance allocation and the book and claim work? • How will SAF be ensured to come from sustainable feedstocks? • In practice, how will the fuel be met in a sustainable way? • Who claims scope 3 reduction from SAF? Challenges/concerns:

		• Actions from the catalogue published by Stargate have not been implemented. • Most airlines expect airports to give incentives and only see airports role as such, incentives are working. • Airports that are state owned vs private have different challenges, state owned can give more incentives. Private airports struggle to convince shareholders on using the money for incentives. • Airports should be involved the conversation. • Strategy implemented: if you fly on SAF you pay less landing fees. • Create awareness with passenger-collaboration with airlines and fuel suppliers	• Smaller airports not connected to the pipeline might have some challenges getting supply of SAF • SAF is expensive, many airports cannot give incentives and airlines are struggling to get SAF • Feedstock availability and pricing of the fuel.
	Large airport in Scandinavia and related consortium 2	Airport as an advocate role. Private airport • Airports not part of fuel supply/value chain, mainly it is a relationship between airlines and fuel supplies. • Infrastructure for SAF should be there to attract "greener" airlines and not lose them to competition. • Infrastructure is ready (hydrant system) for 2% blend. • Conversation with fuel supplier and airline- where SAF is coming from. • Collaboration with airlines (if needed) on educating passengers on SAF, close collaboration urgently needed between consortiums and airports. • Some airports have advantages due to the context they are in or what is in their surroundings.	Questions: • The role of airports in the short and long term in the value chain. • Kind of SAF they should focus on and sustainability of SAF • Infrastructure impacts Challenges/Concerns: • Infrastructure for hydrogen and electric • Business case for sustainability and SAF- difficult to convince shareholders. • Payback on infrastructure for hydrogen and electric • Strong competition between airports, fuel suppliers and airlines • Competition with other airports: if landing fees increase for non-SAF flights, airlines might fly to other airports
	Civil airport operator in Scandinavia and related consortium	Consortium and airport already looking on how to navigate SAF landscape. State owned airport. • Biojet study already in 2012. • Looking into how SAF can be produced locally and how to incentivize it • Airport and consortium involved in many conferences and reports on producing SAF • Airport already blends SAF into their infrastructure-mass balance principle; done with cooperation between fuel supplier, airlines, and airport (initiated by fuel supplier). Costs split between parties involved. • No issues with the physical uplift: passengers accepted it. • Existing infrastructure did not have to change • Airports own the ground: could play a role in opening to other fuel producers, look for potential purchase agreements for airlines.	Questions: • How can SAF be produced locally? • What feedstocks are available locally? Challenges/concerns: • SAF import and paperwork was challenging and took time • Heavy competition between airports • Airports core business is not fuel supply • Value chain issues to supply SAF at smaller airport unless mass balance is applied at refinery. • Meeting the demand for the mandate. • Constant planning for growth could present issues in the industry. • Business models might have to be rethought

		• Educate passengers is important, involvement in other innovative projects (feedstocks locally, technologies, SAF), implement incentive programs. • Big oil has ruled the game, new SAF suppliers could grow • Work with authorities to help the uptake	
	Private industrial airport investors and managers	Focus on private airport • It seems everyone likes SAF and wants it at their airports to drive down scope 3 emissions. • Many shareholders are reluctant on the investment towards SAF due to the price of it. • Airport between fuel supplier and airlines. Airlines want to reduce scope 1 emissions but want airports to pay for their fuel (SAF). • Conference note: Fuel suppliers will put SAF supply where there are incentives. Airports benefit the least from incentives and SAF. Producers need to have a guarantee that the SAF supplied will be taken up. • Airports should not blend on site, for safety reasons. • Airports could incentivize and advertise the usage of SAF, make it attractive to fuel suppliers to deliver to them. Reduce throughput charges if SAF is brought to the airport. • If airports manage to invest into small scale SAF production (e.g: PtL) it would be a game changer. • Airports can investigate how they can produce their own energy. • Good publicity for airports to have 'green flights or supporting it.	Questions: • Why do airports have to pay in order for fuewl suppliers to meet their obligations? • Will infrastructure have to change when there are aircrafts on 100% SAF? Will this bring blending to the airport? • How many years until hydrogen and electric are introduced? • How can airports contribute to such an uncertain environment? Challenges/concerns: • Airports do not benefit from the usage of SAF. • Fuel suppliers might not deliver SAF to airport if refinery is not close by. • If SAF is not being taken up by the industry it will be sold to other industries. • No business case for sustainability at airports, it is cheaper to pollute. • Uncertainties on how it will play out in the long term • Shareholders of the airport might not have same interests. • ESG criteria and reporting
	Large Airport in Benelux area and related consortium, 3	• Consortium interested in the implementation and upscaling of SAF. • Airport aids in demonstrations for SAF flights, as well as assessments and roadmaps. • Airports could work as coordinators and enablers, mainly bigger airports. This could help smaller airports. • Airport is proactive and feel responsibility towards the operations and infrastructure. • Airport as a facilitator, connecting fuel suppliers with airlines. Providing incentives and engaging private and public partners. • Airports contribute to the production and development of SAF and efuels. • Investments on pilot studies. • Private shareholders and airports should be aware of the developments. • Support from authorities needed, implement same mechanism as what it has been done historically with alternative fuels.	Questions: • What other production processes will grow apart from HEFA? • How will the gap between conversion processed will be bridged? • What will be the book & claim mechanisms? • What are the logistical implementations? Challenges/concerns: • Variety of stakeholders, hindering development and investments. • Public vs. private shareholders of airports. • Local and political environment and context might affect airports decisions. • NGO's and activists. • Western Europe and Scandinavia might have most SAF. • HEFA scaling up is limited. • Cheap SAF supply vs expensive one.

		• Airport's role and involvement depends on local context. • Airports could aid in educating passengers.	• Logistical challenges between airports. • Supply chain on SAF: imports • Uncertainties in supply chain.
	Large Airport in Southern Europe	• Biggest portion of biofuels have been used on transport, and it is expected that this will keep growing. • Likely biggest portion of biofuels will go to road since there are more incentives there. • There was more expectation on what airports could and should be doing in the uptake. • Airports could help in the beginning, as part of the delivery of SAF to airports. • Airports can aid in the organization of introducing first batches of SAF. Airports can help in administration and produce papers needed. • Minor changes in pipelines to deliver SAF by pipeline. • Mass balance was the easiest to apply at the airport. • SAF certificate goes to airline who purchased SAF. • Collaboration with oil suppliers needed to ensure safety and intake of SAF to the infrastructure. • Airlines can purchase SAF from any fuel supplier, airports only need to help in first steps. • The government can help give incentives for SAF via airports. • Airports would rather focus on electrifying their operations. • Airports could become energy hubs, and they will likely play a bigger role for hydrogen and electric aircraft • Decarbonization is a common goal, not only airlines or fuel suppliers have this goal. • Airport as coordinator role of policy and lobbyist, to ensure all parties work together. • Airport can play a role in educating passengers on SAF. • Consortium helps in developing and researching innovations. • Blending on site not efficient, poses more challenges.	Questions: • What interactions will there be between sectors needing biofuels? • Who will pay for the SAF? • How will SAF be distributed? Challenges/concerns: • Interaction between the decarbonization of other industries and the usage of biofuel: aviation, maritime and road. • Approvals are needed by many parties for SAF to first enter an airport: safety concerns and certificates. • Administrative problems. • Competition between airports that give SAF and those who do not (airports owned by the state vs. private). • Stick or carrot approach. • Other countries might not follow SAF uptake. • Book & claim. • Airlines might not care were SAF is coming from. • Bigger airports might be the only ones getting SAF. • HEFA process being the most dominant one. • Economics and costs involved with SAF implementation.
Airlines	Ultra-low-cost carrier	• Airline has ESG pillars and does ESG reporting. • The airline expects SAF growth, and many countries follow SAF trends from the EU and UK. EU as trendsetter and others will follow. • ReFuelEU mandates putting obligations on fuel suppliers that are close to the airports. • Airports could play an essential role on securing SAF. • Conflict between cost and sustainability benefits, and between	Questions: • Which airports follow outside of the mandates scope? • How will consumers view book & claim vs physical SAF? • Will penalties affect the airline in any way? • Will we need airports or suppliers to prepare documentation on SAF allocation? • How will we need to cooperate with fuel suppliers and airports?

		competitive advantage and disadvantage. • Airline interested in physical SAF • SAF distribution mainly in western Europe and Scandinavia. • Airports are part of the players, however, cannot do it on their own. • Airports need to prepare infrastructure. • Fuel procurement team from airlines working with counterparts at airports and fuel suppliers. • Cooperating with airports and fuel suppliers to find out more over mandate. • Airports helping with demonstrations, openness from airport to cooperate and help. • Certificate of demonstration from airport side. • Airports can also partake in other projects on sustainability together with airlines apart from SAF. • Underdevelopment from airport side on waste management from airlines. • Airports focusing on big actions to reduce emission, rather than also looking at other routes, such as waste from airlines. • Education on SAF to passengers. • Airline looking into airports where SAF is cheapest. • Airports not part of supply chain but could encourage tests flights and projects using SAF in cooperation with airlines and fuel suppliers. • Airports might not benefit economically, but the PR outcome is positive	• How will the different fuels will be manages at airports? Challenge/concerns: • Securing SAF, airports outside the scope could mean they have less opportunity in uptaking SAF. • Unsure how to proceed since the mandate is not final yet. • Concerns on reporting mandate and ReFuel interactions. • Unfair and unequal SAF distribution over countries • Cost challenge if airports also want to implement SAF before the mandate. • Explaining SAF to passengers. • Concerns on greenwashing and sustainability of SAF. • Production and technological concerns on SAF • Sustainability teams between airports, airlines and fuel suppliers not connected.
	Low-cost carrier	• Sees Airports only as “bus stops”. • Airports should ensure the infrastructure is there and up to date. • Implementation and uptake of SAF is a shared responsibility. • Airports can help facilitate the ramp-up and setting up of the commercial processes: by providing incentives. • Airport can use marketing schemes to promote SAF among passengers. • Airports can focus on electrifying ground operations. • Airports should make operations as cheap as possible, so airlines spend it on SAF. • Airports should focus on facilitating as a role. • Players in the aviation sector should talk to each other and collaborate. • Focus on future infrastructure as well and future technologies.	Questions: • Where do we get the money to pay for SAF? • Will it cost more to get SAF rather than paying the penalty? • Will the penalty cost more than making or producing 1 gallon of SAF? Challenges: • Not all SAF has the same sustainability criteria. • Setting up supply chains at smaller airports. • Price differences between large hub airports vs. smaller ones. • SAF might be distributed to airports that have incentives. • Fit for %% policies are not aligning with each other. • Competition across means of transport on fuel (caps proposed on HEFA). • Feedstock availability in Europe. • Contrasting policy approaches between nations.

	Flag carrier	• Airline also as fuel supplier of SAF to some airport, under the mandate they will also be affected as fuel supplier. • Airline has ambitious goal on SAF by 2030 above the mandate. • Airport's role depends on their own strategies and who owns the fuel supply infrastructure. • Fuel suppliers will likely have the responsibility of ensuring the infrastructure is there, the airport is just there to facilitate. • Airport can provide incentives and stimulate extra usage of SAF above mandate. • Some airlines have their blending facility with fuel suppliers. • Airports are willing to invest on SAF projects. • SAF doesn't have to be supplied at all airports per the mandate. • Airports with more incentives will get more SAF and airlines look for that. • Fuel suppliers might choose to invest on certain airports. • Make customers aware of SAF, airports can help on that. • Airports should communicate with each other and share experiences and knowledge.	Questions: • Which parties own the fuel infrastructure? • Where will SAF be blended? • Who owns the blending systems? • How do you allocate GHG emissions or savings using SAF? • Is it effective to have SAF at smaller airports? • What measures can we implement and communicate to passengers without greenwashing? • How do we prevent double counting on SAF gains? • How will book & claim will develop? Challenges/concerns: • If the airport doesn't support SAF, the offtake is very difficult. • Infrastructural challenges: SAF vs Jet A-1 • Certifications on SAF. • Regulations on SAF. • Sustainability on SAF and feedstocks. • Costs of SAF. Costs and efficiency at smaller airports vs. bigger ones. • Scope 3 emissions. • Concerns on greenwashing. • Tensions between partners and competitors.
Experts and Academics	University – Academic Sector	• Big airport hubs in Europe have been involved in decarbonization themselves and scope 3 emissions, this includes flights. • ReFuelEU mandate might not affect small airports. • If smaller airports invest it might increase their charges. • Big airports and hubs are already equipped to deal with the mandate. • SAF as a drop in can be used in existing infrastructure. • Best practice: If airport generates revenue by fueling, they might have an incentive to diversify themselves. • Each airport should conduct a Cost benefit analysis (CBA) to see what fits them best. • SAF supply to airports might depend on their location. • Airports involve4d in the lobbying process might have advantages.	Questions: • Airports can ask: how is the fuel coming towards them? Understand and map it out. • Do airports see a business case for sustainability? Challenges/concerns: • Overlapping mandates from different countries/regions might impact SAF supply, incentives, and other aspects. • Book & claim system uncertainties • Resistance from local communities and NGOs • Competition between airports to attract airlines using SAF • Misalignment of interests between involved stakeholders • Limits to growth and degrowth
	Emissions Authority - Governmental Body in the Netherlands	Policy for the usage of biofuels on road transport has been in place for a long time now, the policy has driven up the usage of biofuels in the road sector. The current system allows the sector to meet the demanded quotas. • HVO(biofuel from oils and fats, using same feedstocks as HEFA) commonly used as renewable diesel has been the most used one in the industry.	Questions: • How will the road transport obligation will be able to keep up the integration and interaction between the sectors. • How will the biofuels market behave after 2025? Challenges/Concerns: • Competition for the feedstock between industry. • Limits to feedstock availability.

		• Road transport can deliver their obligations by blending or aiding other sectors like the aviation and, maritime sector. • There is a growth on the usage of biofuels in all sectors, voluntary targets are also growing. • The government has played important role in pushing the obligations. • Stakeholder management and participation between governmental bodies, NGO's and companies has been useful. • Road transport can meet their obligations by giving their 'tickets'to the aviation sector	• Overlapping mandates between industry: road transport goals/needs and the aviation ReFuelEU mandate. • Possible tensions between EU mandate and mandates in place for each individual country on other sectors. • Policies in each country on how the fuel is delivered differ and who can claim the SAF passing through the pipeline.
	Independent Consultant – Policy/SAF expert	SAF consultancy and experts growing over the years. Airports can be good at advocating on policy Airports can work as enablers of SAF • Only a niche group of airlines and companies looking into SAF and its production and how to get it to airports. • Airports were immediately removed or not considered for it. • Fuel suppliers and airlines cut the deals with each other. • Limited number of fuel suppliers around the world • In most cases fuel suppliers come and build on airports land and run the fuel supply operations • Airports have limited control on fuel operations • Blending on site not as efficient, and ensure quality control • Airports can aid in the planning on portion of aircrafts being fueled on SAF as the transition goes onwards	Questions: • What will happen in the transition period on where SAF is? • How will infrastructure changes occur, aircraft changes and implementation? How will it transition? Challenges/concerns: • Airlines will make cost calculations since they will not have access to SAF and end up paying the fine • Book & Claim system development • Meeting the demand • Preparatory planning on fleet organization
	Engineering Consultant	• The mandate encourages innovation and deployment. • Airports are facilitators, they can help with aspects that fall under their jurisdiction. • Airports can also help create awareness among passengers, and inform what the industry is doing, initiatives, SAF. • SAF can immediately be mixed into existing infrastructure at airports. • Generally, no new tanks are needed, nevertheless the supply chain should be consulted. • SAF combusts cleaner. • In the long-term minor changes might be needed on infrastructure and operations with mass deployment of SAF. • Airport as the facilitator should stay informed and participate in the supply chain. • Innovation theory can be used, early developers will have fewer risks. As a facilitator you do not have to be an innovator.	Questions: • How to adapt infrastructure and organizational factors to fuel carriers' operation on the airport? • What will be technically feasible in the long-term? Challenges/concerns: • Shortage of feedstocks, competition between sectors for biofuels. • Waste needs to be utilized and incorporated to meet large demands. • Food vs. fuel • Availability of feedstocks. • Price of SAF, parties not wanting to pay for innovations. • Airports without SAF might be less attractive for airlines. • Tunnel-vision on SAF, hydrogen and electric as solutions for decarbonization.

		• Joining early innovators can aid. • Innovators do not wait for regulation. • Airports should conduct impact assessments ensuring everything is up to date for the deployment of SAF. • Airports can be involved in the lobbying process.	
	Airport Consultancy	• Involved in helping an airport consortium. • Many airports have shown interest in SAF implementation; however, many do not know where to start. • Airports should use already published advice and conduct deeper analysis considering local context and other aspects in relation to SAF. • The studies done and the findings on the creation of the catalog define 3 main categories: Stimulating uptake with financial incentives, creating awareness, and taking leadership. • Some type of investment is needed on parts of the supply chain. • Business models should include investments into SAF. • Airports do not have any gains on some of the SAF implementation strategies. • SAF corporate programs, push SAF towards corporate travel. • Airports should be direct with airlines on seeing how they can cooperate with each other. • Airports should be involved in the policies • Airports should understand what their partners (fuel suppliers and airlines) SAF plans are. • Airports taking the lead on SAF will have great advantages in the long-term]	Questions: • Where is the investment needed, down or upstream of the supply chain? • What allows airports to make decisions? Who is making the decisions? Challenges/concerns: • Airports hesitant to go outside their scope of work. • Airports concerned about greenwashing when promoting SAF. • Large competition between stakeholders. • Fuel supply systems and airports are complex, they have different owners and parties involved. • No business case for airports in relation to SAF in the short-term. • Feedstock availability and sustainability.

Appendix V: Personal Notes SAF Congress

Notes from SAF Congress
8th of June:

- By 2050 it is expected to have 47,000 planes in the air in one day, 50 million passengers, and 25% of global CO2. (in 2019 it was 24,000 planes, 20 million passengers, and 2% of global CO_2)
- SAF is considered the most important factor to reduce emissions
- There are currently 150 SAF refineries in the EU and 250 billion euros of investment.

Keynote 9:00 - Panorama of aviation decarbonisation: What are the levers, pillars and solutions available to achieve ambitious emissions reduction goals?

- Lufthansa: views SAF as a game changer
- Fuel use & Efficiency -> Investments needed in technology and manufacturing for improvements
- Aromatics impact the engines and the fuel mix -> Technology fixes are needed
- Investments for SAF are needed however it is unclear where we get the money from.
- Costumers must be integrated into the conversation on SAF uptake. For the uptake of SAF and to convince customers on paying more, the conversation should start with corporate and business customers. Those customers could be more willing to pay a premium which could aid in the diffusion of SAF.
- How can airports assist airlines in adopting SAF? For customer engagement, airports could reach passengers.
- SAF has to be delivered globally to make an impact. To achieve targets, SAF should be available at all major airports
- ICAO- Global vision on SAF deployment
- Focus on SAF vs. other generations of tech such as e-fuels and hydrogen.
- Non-CO2 impacts in aviation must be considered since it contributes to 70% of the emissions from aviation. The warming effect is much stronger than CO2 emissions. However, it is challenging to quantify the contrails and measure their effects.
- SAF has different impacts that have to be assessed.
- Selling sustainability to customers? Make sustainability exciting to customers. Corporations could play a key role in reaching customers. Passengers need to be on board with paying more to use SAF. The industry and corporations should have and have more responsibility on how much to pay for SAF.

Keynote 10: 00 Unpacking policy and regulation: What next for ReFuelEU, RED II, Fit for 55 and the EU taxonomy?

- EASA -> ReFuel EU -> decarbonize aviation
    - Part of Green Deal: level the playing field: fuel suppliers will be obligated to provide SAF
    - Airlines will have to report on fuel tracking (avoiding carbon leakage is a challenge)
    - Airports can aid in: providing SAF access to airlines
        - Mechanisms: it is still unknown if fuel suppliers and airlines will have to send where SAF is coming from and how is being sent.
    - Airlines -> should be able to show to passengers the amount of SAF on a plane
        - Only drop-in fuel : investors: competition between fuels -.biobased SAF vs e-fuels
- Scope 3 challenges: new policies (CSRD)
    - Many policies in place SAF will be directly affected
- HEFA will be playing the biggest role to fulfil SAF requirements
- Other tech will have to break through -> municipal solid waste
    - FT- tech
- However HEFA and and FT will not be enough.
    - Not enough investments
    - Less investments in production the less you will have & produce
- Biofuels need to scale up uncertainty & competition between investors on what to invest SAF or e-fuels

Keynote 11:10: Europe's 2023 Sustainable Aviation Fuels landscape: Projects, pricing & policies
Rob Jan Speld

➔ ReFuel EU – 2025

    - Market -> where are the incentives -> creating the demand on the market
    - 6% SAF for 2030
- ➔ Incentives at airports
- ➔ Sourcing of SAF? Supply chains
- ➔ Airlines look at what is most efficient & cost-effective

Infrastructure: supply side has to look at it.
Honeywell UOP -> HEFA

- 3 million tons to be produced in Europe
- Ethanol to jet technologies
- Investment needed in the entire supply chain
    - De-fossilize or decarbonize
- Question: what is the main challenges in scaling & replicating?

KLM -> achieve 10% -> speed up
HEFA -> limited feedstock availability

Keynote 11:50: Scaling SAF Part 1: The role of governments and public bodies to drive production and deployment of SAF
Equity in SAF pricing, etc

- ➔ ICAO won't lead the pack
- There is a large difference between airports
- Key learning points: Move away from HEFA
    - HEFA cap (could be a possibility to promote other conversion technologies) -> protecting the supply on feedstock
    - Knowledge transfer & collaboration are needed to meet the demand
    - Allow local initiatives & regional differences
    - Collaborate rather than compete with other industries
    - 100% SAF major innovations upcoming in the future
- HEFA ->pig fat as source (problematic)
- Limits? ->to what extent is there a limit to growth (Mateo Mirolo) airports, airlines and fuel suppliers not planning on a non-growth scenario

Keynote 12:30: Airline perspectives and sustainability levers: Evaluating SAF, operational efficiencies and new technologies to hit decarbonisation targets

- SAF policy: climate impact of airport on operations
- KLM has higher SAF targets than mandate (10% by 2030)
- Not all SAF is the same and the sustainability criteria for each is and should be different
- SAF-> should be viewed as medium to short term solution
- Airlines can voluntarily go above mandate(KLM) or just the complying level(wizzair)
- Lufthansa-> aiming to go above mandate
    - They are looking into the sourcing ofSAF
    - Increase awareness between employees and customers
    - Honesty on SAF pricing and how flying will get more expensive
- KLM -> mandatory ticket price approx. 1% of ticket price will go towards SAF purchase
    - Hard to make big moves in the industry due to competition
- Vueling-> offering SAF purchases to passenger
- Business case for sustainability rising and more focus should be put on this
    - Customer pressure on sustainability-> EU can be seen as trend setter on sustainability mandates
        - Customer insight team: perceptions on SAF and sustainability
        - Feedback on customer
        - Offer transparency to them
    - Education on passengers
- Air New Zealand views themselves as a polluter and wants to avoid green washing claims by remaining transparent and honest to customers

    - Greenwashing round table was set
- KLM and other airlines have faced backlash on greenwashing, transparency on what they know and what they do not know
- Lufthansa is also concerned with greenwashing and questions what and how to tell customers information.
    - They offer compensations
    - Focus on transparency : portfolio projecs
    - Seeing is believing

Book & claim vs. Mass balance

- KLM trying to use the mass-balance approach on their flights
- Pricing-> iit will certainly be more expensive(tickets) and it is needed to be transparent on the prices to the customers
- Airlines have not reduced their growth forecast (airports adapt to these forecasts)
- Airlines are main polluters in the industry (scope 1)

Keynote Stream 2, 14:15 : The Net Zero Roadmap for airports: Assessing and managing Scope 1,2 and 3 emissions

Stargate 30: 3 main aspects: passengers, direct and indirect employees

- Decarbonization
- Looking into other solutions apart from SAF
- Digital twin

Airport -> is an energy node and could become or be seen as an: ENERGY HUB

- Airports can also focus on operation electrification
- See what can be done in SAF: scaling up(main issue that has not been looked at)
    - Infrastructure challenges (if any)
    - Passengers -> education
    - Circular airports
    - Move airport operations to net zero by 2050
- Taxing -etaxing
    - Reducing emissions
- Airports as energy hubs: solar storage-battery storage

Regulation: what does it mean for airports?

- What role should they play in the SAF value chain? In Copenhagen it is not part of the value chain
- SAF available at airports?
- Investing or buying |SAF as an airport has no economic benefit
- What the role of airports will be is still in question

TULIPS: believes airports can play a role in ReFuel

Keynote Stream 2, 15:00: Airport masterplanning & future fuel infrastructure: What planning is required to keep pace with sustainability & infrastructure changes in the airline industry?

Airport master planning

➔ SAF in airports and developing own SAF on location (AGS airports)

SAF -> phil -> Teesideaiports

➔ The feedstock is available in the region.
➔ SAF plant 6 miles from the airport
➔ Shareholders also own feedstock close to the airports
➔ Investments into SAF projects

- Advice: do not have permanent infrastructure built, instead have adaptable infrastructure that can easily change or be adapted to rising technology and innovations.
- Airports can become energy hubs: focus on ESG and waste

    - Airports produce a huge amount of waste: waste could be used as e-fuel or repurposed into something else (further research and adaptability needed)
- Planning: hydrogen on site
    - Key points: governments play an important role
    - Hydrogen fuelling stations
    - Generations
    - Buying fuel from airports: airports as providers
- Airports are currently not considering a scenario where there is a limit to growth
- Regional airports are thinking about this scenario

Stakeholders should plan (master planning) on what the demand will be if alternate mandates are in place where growth is limited

➔ Funding from gov. is needed

- EU -> infrastructure acceleration need (hydrogen and SAF)
- Fund structures inside the entities to allow private investors to enter

Private investments are needed
Stakeholder engagement is crucial

Keynotes Stream 1, 16:45: PtL and eFuels feedstock and technology focus: Evaluating the dierent feedstock and technology pathways

PtL & eFuels feedstock & tech focus

- Evaluating the different feedstock and tech pathways
- Efuel producers: production plans are needed
- Country and industry competition for funding & fuel
- Huge gap -> on filling the energy demand
- Incentives for fuel producers are needed to level the playing field
    - Example of solar industry (boom of solar after gov. incentives)

Keynotes Stream 2, 16:45: Comparison of decarbonisation solutions for small, medium and large airports: What prospects for hydrogen and electric aircraft, distributed generation and renewable energy?

- Subsidies and lobbying for SAF needed
- Competition between USA & EU to meet SAF mandates and demand: both need subsidies
    - Many are waiting to prices on SAF to go down
- Medium term solutions needed:
    - SAF needed at all major airports to ensure mandates can be met
    - Book & claim; report on voluntary targets. Do not wait till it is mandatory
- Airports have to focus on care delivery-> safety of aircraft
- The transition to SAF has to be managed with partners
- Suppliers need to certify jet-fuel with blend
- Airports do not need a specific mandate
- Airport infrastructure: quite minimal changes needed for SAF uptake
    - Primarily changes are not needed to meet short term mandates.
- Airports cannot stand still and wait for mandated

Keynotes Stream 2, 17:30: Airports and SAF: Developing effective supply chain, blending and logistics capabilities

- Airport supply chain: use of the airport and strategy to implement SAF.
- Even if SAF is not available at airports greenwashing mechanism can take place:
- Arvid Løken: Avinor: SAF not available at all airports
    - It is also costly
    - Not realistic to have SAF at all airports, unless SAF is blended at the refinery already
- At beginning start at hub of airport blend with existing off-site
- Space at airports is a premium
- Blending onsite doesn’t make sense
    - Better to do it before fuel reaches airport

    - Space is a limitation on what airports can do
- Role of airports: what an airport can do in value chain?
- Gathering: industry unions, set SAF in the agenda: in Norway it is in the political agenda
- Policies are needed to get the production up to meet mandates
- Airports must work on the voluntary side of decarbonization
    - What to do beyond the mandate has to be asked.
- Jordi Candela: Create SAF friendly airports. If you have land available, you have capacity to deliver. Implement SAF in facilities.
- Social impact of what an airport can have.
    - Role of airports
    - Regional airports
    - Attracting investment
    - Consortium with other airports and parts are needed to scale up and make it cost efficient.
    - Look beyond their sector to enhance the uptake of SAF.
- Airports have to talk to each other airports and reach out to manufacturers, logistics, etc to see how they can implement SAF and facilities to the region.
- Difference between state vs. privately owned airports
    - Landing charges: might push or attract airlines if these are modified.
- Airports are fairly neutral actors -> stakeholder that connects other stakeholders.
- State owned airports could have an advantage
- Decentralization of airports -> independent airports might have to take a risk
- What can airports do with the policies?
- Airports can only help in logistics at the moment; however, they can start preparing for hydrogen.
- Infrastructure always give way to drive the technology for the future.
- Airports should focus on more than one technology: Multi fuels
    - Hydrogen storage tanks
    - Safety issues
    - Work out what is needed now for the future.
- Airports can do now:
    - SAF for own business travel
    - Voluntary targets on SAF and decarbonization
    - Kickstart the market
- SAF is expensive

DAY 2: June 9

Keynotes 9:00: The energy transition, aviation and the energy trilemma: What is the pathway to combining affordability, energy security and low carbon solutions?

- Mandates alone will not be enough; policy is a vital process for decarbonization.
- All SAF opportunities are required
- Adversary is fossil fuel industry
    - SAF should not be compared to net-zero
    - Sustainability should be at heart.
- Main concern: How will SAF be financed?
- Ikigai: Decarbonization means improved profitability.
- Airports can focus on own generation of energy, but they have land constraints.
- If you are funding a new aircraft why not fun SAF instead/as well?
- Approx 175 billion euros per year for SAF build-up and for decarbonization.
- Education is important
- 1.9 trillion euros requires to meet Paris agreement scenarios on SAF.
- Ticket prices will increase
    - Decarbonization will cost the costumer or taxpayer
    - The industry is capital intensive
    - Accessing financing is difficult

    - EU-> sustainable finance framework
- Governments need to build the demand.
- Carbon pricing and tole of offsets
    - SAF offsets
    - There is much uncertainty
- Where are the offsets going?
- Airlines and fuel suppliers are not happy about the mandate.
- Investors might listen to mandate; this could create certainty.
- Airports should not be involved in investing, only in infrastructure
    - Funding should go to their core operations
    - On-sire energy
- No action needed from airports to implement SAF
- Mandate: how it will be scaled up and how will it be funded?
- Airports can aid in cooperation, sketch out risk maps
- Work together is needed.
- Interdependencies have to be understood, sharing information is crucial.
- No formal accounting mechanism on how to claim the book & claim.

Keynote 12:15 - Deep dive into book and claim, mass balancing and chain of custody: Evaluating the most effective way forward?

- Sustainability certification scheme in the biofuel space
    - From feedstock to production
    - Ensuring feedstock sustainability
- SAF registry -> principle of book & claim
- Book & claim more efficient
    - Meeting the demand
- SAF usage: make it auditable
- SAF registry needed
- Risks on double counting
- No clear indication on the quality of SAF and sustainability performance of SAF
    - No standardize wat of handling it
- Misinformation with protocols and book & claim