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Sustainability in Aviation

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ABSTRACT

The environmental situation is getting worse every year. Tourism, as one of the largest industries, is a part of the problem. Aviation is perceived as one of the biggest polluters, especially contributing to air and noise pollution. This research investigates whether the airlines have developed sustainability strategies and plans for the future in regards to environment and sustainability. Specifically, it investigates four chosen airlines and analyses their strategies.

The theoretical sections offer a better understanding of tourism as a concept and connected means of transportation the tourists can use to show there are alternatives to flying and their possible pros and cons. There are also described negative impacts aviation has on the environment. After the introduction to the problematic of tourism, sustainability is described. Following is sustainable development in general and in tourism. There are sustainable strategies talked in-depth, including the stages of sustainable strategies the business can have and key principles these strategies should be developed upon. Also, two sustainable projects from international aviation organisations are introduced and described.

The qualitative method of obtaining data was chosen over quantitative for the needed results and the importance of insight into the airlines' sustainable strategies. This would not have been possible with the quantitative method; the results would be different or would not help to answer the research question. The data from airlines' websites and reports were collected, described and analysed using the thematic analysis while comparing the data to the sustainable stages and key principles. The airlines themselves were also described in short with their history and important milestones.

The analysis answered the research question and showed that the airlines do have sustainable strategies and plans for the nearest future. It showed the airlines have three main strategies with a common topic, being the CO2 footprint, waste management and social project involving partnerships or helping those in need. The CO2 footprint projects were focused on fuel efficiency, optimizing the flight routes, replacing old aircraft for the younger ones or, two airlines, had projects about sustainable fuel. The waste management strategies were focused on recycling, replacing single-used plastic or saving water and energy. Every airline had a different level of recycling waste and two had one-time projects like recycling old billboards or uniforms. The social projects were mentioned to show the sustainability is not only about the environment. The airlines had projects focused on helping various groups in need, like veterans or children. 2 Only Finnair did not have a similar project, instead, they highlight the partnership with various sustainable organisations.

It was concluded that the airlines do have sustainable strategies and plans for the nearest future regarding environment and sustainability. The research was made on four airlines using the information from the website without the

possibility to ask additional questions because none of the representatives answered to author's email. The research also showed the need for further examination of the topic and how sustainable is the airlines' behaviour in certain points.

Keywords: **Aviation, airlines, tourism, sustainability, sustainable development, sustainable strategies**

REVIEW OF LITERATURE

The chapter introduces insights into the aviation industry, followed by concluding remarks on how to improve efficiency. Thereafter, the alternative technologies; sustainable aviation fuel (SAF), hydrogen, and electric-powered aircrafts are presented. The chapter ends with the findings related to policies and regulations.

Aviation Industry

The aviation industry has rapidly expanded since the inception of commercial jet flights at the beginning of the 1950s and has become a significant pillar of modern society. The industry has been powered by fossil fuel and despite the fuel efficiency improvements the industry's growth has made it one of the fastest expanding sectors in the global economy in regards to GHG emissions (Kim et al., 2019). As of today, the commercial aviation industry is facing challenges in balancing the rising demands of passengers with anticipated growth, while complying with progressively rigorous environmental regulations as well as emission commitments.

Aviation industry as a socio-technical system

As noted by previous studies, the aviation industry faces major challenges in adapting and transforming towards a sustainable future (Kim et al., 2019). First of all, the alternative solutions for replacing fossil jet fuel, such as sustainable aviation fuel (SAF), hydrogen, and electric solutions face major challenges for powering the future of commercial aviation. Secondly, the aviation industry can be considered composed of an intricate network with different stakeholders and actors, as shown in Figure 1.

Figure 1. Socio-technical system for aviation (Geels, 2006).

Figure 1. depicts the aviation industry as a socio-technical system that comprises various elements such as technology, regulations, infrastructure, supply networks, and user practices (Kim et al., 2019). Consequently, the transition to sustainable alternatives to fossil jet fuel is increasingly demanding as all these aspects need to be considered. Nonetheless, among the alternative solutions mentioned earlier (SAF, hydrogen, and electric), SAF appears to be the least challenging option in terms of the socio-technical system as it can be used as a drop-in fuel, thus obviating the need for new infrastructure and airplane adjustments (IATA, 2022). Nevertheless, realizing new sustainable solutions necessitates extensive research and development. Additionally, the implementation of new technologies and the necessary infrastructure poses significant challenges to technological transformation, due to their long- life cycles and substantial sunk costs. Therefore, the integration of novel technologies and alternative solutions in the aviation industry is bound to encounter major impediments.

Alternative Fuels and Technologies

The aviation sector aims to embrace sustainability, resulting in a heightened focus on substitute fuels and innovative technologies to substitute conventional fossil-based jet fuel. Currently, the most feasible option for commercial aviation to achieve this is through the use of sustainable aviation fuels (SAF). While other low-emission technologies, such as electric and hydrogen- powered aircraft are not yet available for commercial aviation, it's expected that over time, these solutions will have a significant impact on the industry. Although sustainable aviation fuels, such as advanced biofuels and electro fuels, are recognized as the near-term solution to decrease emissions, hydrogen fuels, and electric propulsion systems are proposed as the future for achieving carbon-free aviation.

Sustainable Aviation Fuels

The umbrella term, sustainable aviation fuel (SAF) refers to fuels that are obtained from non- fossil sources, known as feedstock. The production process of SAF works towards closing the carbon cycle and reduces life-cycle emissions compared to conventional jet fuel. Additionally, SAF aims to meet high standards of sustainability, waste water, or causes harm to the environment, unlike fossil fuels that emit 'new' carbon into the atmosphere, SAF has a short lifecycle and recycles CO2 absorbed by the biomass used in the feedstock. This can result in reduced lifecycle CO2 emissions by up to 80%, depending on the feedstock (ATAG, 2017). Therefore, airlines can replace conventional jet fuel with SAF in order to significantly lower their well-to-wake (WTW) GHG emissions and improve total carbon intensity. As of today, These SAFs are designed to be integrated seamlessly into the existing fuel infrastructure at airports and can be blended directly with conventional fuel. Furthermore, the SAF can be categorized into four different 'generations': (1) biofuel produced from harvested crops; (2) biofuels produced from non-food crops or feedstocks from different waste streams, such as agricultural residue and used cooking oil; (3) biofuels produced from algae; and (4) synthetic fuels, such as Power-to-Liquids (Pt.) produced from renewable hydrogen (electrolysis) and captured CO2 (SBT, 2021a). As of today, SAF has been used in over 450 thousand flights and can be blended up to 50% with conventional jet fuel (IATA, 2022).

INTRODUCTION

Environmental and climate protection received a different dimension of attention since the young climate activist Greta Thunberg started her "Friday for Future "strike in late 2018. By now, her movement slopped over to many countries all over the world as Greta has become a role model fighting for climate protection. While the automotive industry had suffered severe problems regarding the worldwide Diesel scandal in 2015 (Hotten, 2015), through Greta, light is shed on other transport industries that influence one's individual carbon footprint: the aviation industry (Asquith, 2020). Because the emissions produced by this industry are growing very fast, the European Commission forecasts an increase of 70 percent in global international aviation emissions compared to the year 2005 (European

Commission, 2020a). This is why actions for a more sustainable aviation industry including all its actors are urgently needed.

The fast-growing aviation industry has called for much academic research from many different fields of interests — from technical studies to psychological studies. Research referring to the aviation industry mainly focused on airline companies because they are the responsible actors that operate the environmentally contentious flights. This is why this research as well focuses on the airline operators as the responsible parties for the environmental impacts. Nevertheless, there are other interesting actors involved in the aviation industry, such as aircraft manufacturers, or Air Navigation Service Providers (ANSP). However, the analysis of such actors would be beyond the scope of this study. Sustainability and especially its reporting have become a recently addressed topic that can be best related to airlines within the aviation industry.

The diminishing of Earth's resources came to light in the past decades (Scoones, 2007). After that, many notions began focused on ensuring the planet and its ecosystem will not be permanently damaged and will be able to serve the next generations. Because of these efforts, a clear strategy of sustainability was made in the mid-1980s (Portney, 2015). Firstly, it was just about businesses and ways to fight climate change but in time the strategy gradually came into almost every aspect of life, personal or companies as well as getting more and more research attention and topics (Portney, 2015).

Because tourism also continuously became part of everyday life, sustainable strategies and pursuits too started taking root there. It may have started slowly but gradually evolved into the whole research topic of sustainable tourism and continuous strategies about how to make people's travelling less and less harmful to the environment (Harris, Griffin, & Williams, 2012).

It became a challenge, as the number of tourists grew every year before the pandemic started in 2020 (INTERNATIONAL TOURISM AND COVID-19, 2020). The companies had to revisit their business strategies and methods and rework them or even made completely new business procedures that incorporate the sustainable efforts going on in society. It also became more and more apparent that tourists started expecting the businesses to behave sustainably, so more and more certification and other means of showing the company's eco-friendliness started to appear (Harris, Griffin, & Williams, 2012). Airlines were, and still are, seen as one of the biggest polluters in the tourism industry (Harrison, Masilo, & Vardoulakis, 2015). As mentioned, the number of tourists grew every year before 2020 so according to that the traffic grew too. The number of flights was growing so the point of air traffic not being sustainable and environmentally friendly came to light. Even after the announced end of production of the biggest passenger plane A380 (Ahlgren, 2021) and the announced end of production of the second biggest one, B747 (Slotnick, 2020), for 2022 the belief of air traffic polluting the environment in the future more and more persisted. Airlines have projects and research going on the question of sustainability, but many of these, like finding more sustainable fuel, require a longer time to find and test.

However, some of the airlines changed their strategies and inside process for a more sustainable one. For example, not many airlines are giving out meals on shorter flights anymore. Of course, it can be argued it was more cost-related, but the point with less weight, therefore less fuel spend stands. The interest of this thesis lies in the sustainable strategies some of the airlines 6 developed. The author hopes to analyse the strategies, compare strategies of different airlines and maybe gain a bit of insight into what the airlines plan for the future. To get all of this information, an analysis of the airline data on websites will be conducted.

The thesis itself will be divided into theory and analysis. The theory itself will consist of a literature review on relevant topics such as tourism, aviation or sustainability. This part will give the theoretical framework to be referenced in the second part of the thesis, where the analysis of the airline's business strategies, its sustainability and possible future visions will be carried. The information will be gathered from public sources as are airline's websites and annual reports. The conclusions will, hopefully, answer the research questions stated and will give more insight into the industry that is generally seen as a polluter and not sustainable enough.

BACKGROUND

The aviation industry plays a significant role in global society and transportation. However, the industry contributes to climate change through the combustion of fossil jet fuel resulting in greenhouse gas (GHG) emissions as well as noise pollution and air quality issues (Grewe et al., 2021). In fact, the aviation industry accounts for around 4% of global anthropogenic greenhouse gas (GHG) emissions (Ritchie, 2020). As the world is continuously aiming for reducing the climate impact and limiting temperature rise in line with the well-below 2oC target of the Paris Agreement, it is essential that the aviation industry needs to reduce its climate impact (United Nations, 2023).

Currently, there is a vast interest in policies and regulations regarding the reduction of the climate impact from the aviation industry (Grewe et al., 2021). However, as of today, the commercial aviation industry is essentially powered by fossil jet fuel (Kaliks et al., 2019). Nevertheless, the Air Transport Action Group (ATAG, 2011) states that low-carbon, sustainable aviation fuels (SAF), particularly alternative drop-in fuels with biobased components, play a crucial role in achieving carbon-neutral growth. Therefore, the acceleration of the transition towards sustainable aviation fuel becomes crucial for the aviation industry, in order to meet the climate goals and reduce GHG emissions. Other potential low-carbon technological solutions include hydrogen, electric, or hybrid powertrains (Dahal et al., 2021).

Airbus has the ambition to develop the world's first zero-emission commercial aircraft by 2035, which will be powered by hydrogen propulsion (Airbus, 2020). Furthermore, small commercial airplanes will be available for short travel in the late 2020s (Heart Aerospace, 2023). Nevertheless, until other commercially available technologies are available, SAF remains as the only solution for replacing conventional jet fuel.

Furthermore, policy support remains important for the rapid deployment of renewable aviation fuels, as they are not anticipated to be cost-competitive with fossil jet fuels in the near future (Bows-Larkin et al., 2013). 1 The Science-Based Targets initiative for the aviation sector is a crucial effort to reduce greenhouse gas emissions and combat climate change.

It is a collaboration between several leading organizations, including CDP, the United Nations Global Compact, the World Resources Institute, and the World-Wide Fund for Nature.

The initiative provides guidance and support to companies in the aviation industry to model Science-Based Targets based on the Sectoral Decarbonization Approach (SDA). This allows them to reduce their carbon footprint in line with the goals of the Paris Agreement to limit global warming to well below 2oC. The importance of SBT in the aviation industry cannot be overstated. Aviation is a large GHG emitter and a growing industry, therefore, it is crucial for companies in this sector to take action to reduce their impact on the environment. By setting Science-Based Targets (SBT), companies can demonstrate their commitment to sustainability and position themselves as leaders in the transition to a low-carbon economy, which will influence both customers and investors.

Furthermore, the Science-Based Targets initiative (SBTi) helps ensure that companies take meaningful emission reduction actions, rather than relying on unproven or insufficient solutions. In the face of the urgent need to address climate change, SBTi can potentially provide a clear and scientifically-grounded path for companies in the aviation sector to reduce their emissions and contribute to a more sustainable future (SBT, 2021a).

RESEARCH OBJECTIVE

Purpose

The thesis aims to provide insights into the challenges and potentials of the alternative technologies, and investigate the challenges and opportunities for airlines to commit to the science-based targets initiative (SBTi) and thus reduce emissions in line with the Paris agreement. Therefore, this paper contributes with insights into how an airline company can reduce emissions by offering a new perspective and pointing out areas that are crucial as well as areas that require further research.

RESEARCH QUESTIONS

Based on the consideration introduced, the following research questions will guide the research:

1) How can airlines set emission reduction targets in line with the Science-Based Targets initiative (SBTi)?

2) How does the emission reduction strategy differ, based on different scenarios?

3) What are the mechanisms that drive the correlation between national governments' measures of sustainability and sustainability measures reported by airlines?

RESEARCH HYPOTHESIS

H1. Airlines that adopt sustainable aviation fuel (SAF) as part of their operational strategy report significantly lower greenhouse gas (GHG) emissions compared to airlines that do not.

H2. The presence of national aviation-related environmental policies (such as carbon taxes or SAF mandates) positively correlates with the sustainability measures adopted by national airlines.

H3. Consumers are more willing to support airlines offering 'green tickets' when there is a clear and transparent communication of SAF benefits and CO_2 reduction.

H4. The integration of multi-level perspectives (MLP) in airline strategy results in more comprehensive sustainability plans, especially in terms of long-term emission reduction**.**

H5. Airlines that publish sustainability reports are more likely to adopt Science-Based Targets initiative (SBTi) guidelines than those that do not.

RESEARCH DESIGN AND METHODOLOGY

This section introduces the overall methodology used in the thesis. First of all, the research setting, design, and the process are described. Thereafter, a description of the data collection, including the conducted interviews, coding procedure, and ethical consideration is presented. Furthermore, the scenario framework and development are introduced. The chapter ends by discussing the research quality

RESEARCH DESIGN

As stated in the introduction, the study focuses on examining the SBTi implications and possible GHG reduction pathways and scenarios. Given the extensive nature of the topic, it was deemed suitable to utilize both qualitative and quantitative methods to attain a thorough understanding of the research question. Thus, a mixed approach was used to ensure the collection and analysis of qualitative as well as quantitative data fulfilled the study's objectives.

The research focus plan was initially to investigate the topic from a broader viewpoint to obtain a global context. The aim of the qualitative analysis was to gather information regarding SBTi and the commitment process it entails. Furthermore, concluding remarks on the aviation industry, alternative technologies, and policies and regulations were conducted. The qualitative analysis stands as a solid base for the quantitative analysis, which aims to present different scenarios for airlines to reduce their GHG emissions in line with the SBTi. Thus, the data used in the scenarios are a combination of literature review and interviews.

As previously mentioned, the study consists of a mixed approach using both qualitative- and quantitative methods and data. While the two analyses work closely together in order to answer the purpose and the research questions of the study, it was necessary to structure the research process by focusing on each part separately. The first part involves the exploratory qualitative study, which aims at answering the first research question;

1) How can airlines set emission reduction targets in line with the Science-Based Targets initiative (SBTi)? This includes analysis of various aspects including the aviation industry, alternative technologies such as SAF, hydrogen, and electric, policies and regulations, and SBTi. The first phase of the study involved conducting a literature review to acquire general knowledge and establish the thesis structure. Subsequently, interviews were conducted to gather additional information and fil any data gaps identified during the literature review, in order to address the research questions. With the completion of qualitative data collection and analysis, the study progressed towards quantitative analysis. The quantitative analysis was conducted based on the data gathered from the qualitative analysis. Furthermore, the quantitative analysis was conducted by using Google spreadsheet, in order to calculate and plot the different scenarios, with the aim of answering the second research question;

2) How does the emission reduction strategy differ, based on different scenarios?

Finaly, the multi-level perspective (MLP) framework was utilized to analyse the results and scenario outcomes.

METHOD OF DATA COLLECTION

The data consist of both literature findings as well as interviews and additional information. The interviews have a major role in fulfilling the data gaps needed for the scenario analysis.

Interviews

The interviews were chosen to follow semi-structured, open-ended questions, allowing for a more informal approach and the opportunity for follow-up questions. Furthermore, the interviews differ from each other depending on the expert area of the interviewee and thus the area and purpose of the interview. Moreover, ethical consideration was followed, leaving the interviewees anonymous.

Total of 5 interviews were conducted digitally (Zoom, Google Meets, and Microsoft Teams). The interviewees include the following; SAF producers, Airlines, Aircraft producers, SBTi experts, and other experts within the field. The interview questions were all related to the purpose of the study and to get additional required data in order to answer the research question. Additional information can be seen in Table 1, where the description, role, topic, and date of the interviews are presented.

Interviewee	Description	Role	Topic	Date
1	Jet Fuel Procedure	CLC Officer	SAF	April, 2025
2	Jet Fuel Procedure	CLC Officer	SAF	April, 2025
3	Jet Fuel Procedure	CLC Officer	SAF	April, 2025
4	Aircraft Procedure	Director	Future Aircrafts	April, 2025
5	Airline	Manager	Sustainability	April, 2025

Table 1

QUALITATIVE FINDINGS

In this section, the qualitative results are presented in relation to the research question and purpose, while also being connected to the multi-level perspective. The section begins by introducing the aviation industry and alternative fuel technologies. Next, the policy and regulations, along with the Science-Based Targets initiative (SBTi) findings, are discussed. Finally, three summary tables are provided to highlight the most significant findings in their respective areas.

Aviation Industry

The aviation industry has grown rapidly since the 1950s, making it one of the fastest-growing sectors in terms of greenhouse gas emissions. However, as the aviation industry is still almost completely powered by fossil jet fuel, the industry faces challenges in adapting and transforming toward a sustainable future. The alternative solutions are facing their respective challenges, which by itself makes it difficult to move away from fossil jet fuel dependency. Moreover, the industry is considered a socio-technical system, with various stakeholders and actors, and the transition to sustainable alternatives necessitates considering various aspects such as technology, regulations, infrastructure, supply networks, and user practices. While alternative technological solutions are having its challenges, sustainable aviation fuel (SAF) appears to be the most suitable and least challenging option in terms of the socio-technical system. Furthermore, while the industry has set ambitious goals to tackle GHG emissions, the projected industry growth could make it even more challenging. In fact, the projected passenger expansion and business-as-usual projections indicate around a three-fold growth in terms of CO_2 emissions by 2050. Thus, it will require remarkable progress in order for the aviation industry to reach its net-zero targets for 2050.

Nevertheless, while policies and incentives remain crucial for the industry to be able to meet the targets, other environmental concerns like 'flight shaming' are supplementing the industry's emissions targets. Especially in the modern world, where people are more aware of both the environment as well as their power as a customer. The concept of flight shame has in fact led to increased concerns about the environmental impact of air travel, and various European governments have taken action to reduce emissions. However, research has shown that the public's understanding of the impact of air travel on emissions is limited. SAF has the potential to become mainstream, however, public awareness and perception of their use is currently limited. As the aviation industry adopts new technologies, customers may face higher ticket prices, and research suggests that consumers are more willing to pay for sustainable tickets if the reduction in emissions is significant. However, this willingness is limited if the ticket price increase is too high.

Thus, the findings suggest that it is crucial for the aviation industry on a regime level to evolve and enable low-emission niche technologies to gain traction and challenge the established conventional jet fuel technology. Not being able to do so could result in further challenges from the landscape level, which might result in the industry not being able to meet its climate targets, as well as a worsening public attitude towards flying, which might put the whole industry at risk.

Sustainable Aviation Fuel (SAF)

Sustainable aviation fuels or more precisely, biofuels, is the only proven commercial technology able to replace conventional jet fuel. However, while global SAF volumes still represent less than 1% of jet fuel, it is expected to grow rapidly and is believed to cover a significant share of the market. While electric and hydrogen solutions for commercial purposes are still under development, SAF has already been tested for years and can today be blended up to 50% with conventional jet fuel, depending on the feedstock. Furthermore, while the two other alternative technologies are important in order to reach net-zero in 2050, it seems as if SAF is the most suitable option, particularly for long-haul flights where other alternative solutions energy density becomes a limited factor, see Appendix D. As of today, SAF has the possibility to reduce life cycle GHG emissions by up to 80%, depending on the feedstock. The variety of available feedstocks for biofuels indicates that the SAF producers are able to choose their feedstock based on price and availability. Additional feedstocks and production methods are being investigated continuously, and as mentioned by one of the interviewees, all bio- organic feedstocks with high concentrations of hydrocarbons that could be produced in a cost- efficient way are of interest.

Furthermore, from both the SAF producer's and the major aircraft producer's perspective, SAF is seen as the most crucial solution in order to reach net-zero emissions in 2050, see Appendix
D. While the price-premium to conventional jet fuel is around three times higher, it is still seen as the best cost-efficient solution. Reasons for this are that no significant infrastructure changes are required and while the cost is around three times higher than conventional jet fuel, it is still relatively low compared to the other alternatives. Nevertheless, as noted by the interviewed airlines, convenience, cost, and reliability are highly important for airlines, which is why SAF remains the most desired solution for reducing GHG, see Appendix D. Furthermore, airplanes don't require any changes in order to fly with a 50% SAF blend, and require only some small changes if a larger blend percentage is desired. However, major airplane producers like Airbus are working on making airplanes that could entirely be powered by SAF as of 2030. This is a proper example of how important it is for the socio-technical regime to work together.

While the transforming aviation industry is highly required to increase the share of new niche technologies, the cost for the airlines will also increase. Especially in the near-term, airlines need to adjust to additional costs and come up with new economical solutions. One such solution is to sell 'green tickets' which gives their customer the option to reduce their own GHG emissions, by flying with a higher SAF percentage, for an extra fee. This can arguably be seen as a win-win, since the customer has the option to reduce their in-flight emissions, while the airlines get an additional needed revenue stream, which more or less pays for the extra fuel costs. Therefore, it is highly important for airlines and in fact, the whole regime to make sure their customers are aware of sustainable solutions. By advertising sustainable solutions, and making sure that the public is increasingly aware of the challenges, additional revenue streams from 'green tickets or other similar solutions could be increased.

Hydrogen

Hydrogen is a promising alternative to fossil jet fuel due to its relatively high energy density per unit mass and its possibility for zero-emission flights. Furthermore, hydrogen can be produced sustainably by using renewable electricity during production. However, there are some challenges with the technology. First of all, hydrogen as a jet fuel requires modifications to both the aircraft and the engines. Secondly, the produced liquid hydrogen must be stored at extremely low temperatures, indicating that the hydrogen needs to be kept inside highly insulated tanks rather than in the wings, where space is limited, and proper insulation cannot be achieved. Additionally, since large-volume tanks are needed, the aircraft designs would also have to be adjusted, especially for longer flights containing even larger hydrogen fuel tanks. Nevertheless, as the director of the aircraft producer pointed out, while the energy density is higher than for electric planes, it is still a major challenge.

Nevertheless, hydrogen, much like electric-powered aircrafts, are still undergoing development and testing, and there are uncertainties surrounding its potential use in aviation. However, all interviewees believe that hydrogen-powered aircrafts are an important part in order for the aviation industry to reach net-zero in 2050. However, their points of view seem to be divided on how the hydrogen technology will form the industry. Some of the interviewees believe that hydrogen-powered aircrafts will take over the long-, and medium-haul flights, while others believe hydrogen will only be used for short-haul flights. In fact, the interviewed director of one of the main aircraft producers mentioned that the energy density challenge regarding both electric and hydrogen technologies is why SAF remains the most suitable option for long-haul flights, both on a 55 short- and long-term timeframe. However, with further improvements, both niche technologies could increase their market share and help the industry reach net-zero by 2050.

Electric

Compared to SAF, electric aviation is still in its early stages. However, while the future of eclectic aviation is still uncertain, there is a generally positive forecast for the future of electric aircraft, particularly for commercial short flights. The interviewees believed that electric aviation will become a common solution in the near-term future, especially for short-haul flights and where road or train infrastructure is lacking. Nonetheless, electric aircraft will have a smaller size and fewer seats, indicating that more flights will be required to compensate for the capacity of conventional planes flying similar distances.

Moreover, as of today electric aviation does not support the current infrastructure, and thus, a shift towards more electric powered aircrafts will require airports to adapt to the new technology. Additionally, as some of the interviewees pointed out, it is unlikely that electric flights between main airports will occur in the early phase, but will instead cover shorter regional routes between smaller regional airports. The energy density of the battery introduces vast challenges for the technology. As the possible range for fully-electric commercial airplanes (30-seater) is predicted to be around 200 km in the late 2020s, hybrid options are needed. Some of the interviewees stated that in order for electric technology to really penetrate the commercial aviation market, vast improvements regarding energy density are needed. Additionally, the understanding of customers’ readiness for the technology is still lacking and

it becomes crucial for the industry to reduce the possible risks and uncertainties in order to make sure that the technology becomes accepted not only by the regime but also by the socio- technical landscape.

POLICY AND REGULATIONS

While electric and hydrogen technologies are still in their early phase, policies and regulations have been introduced for SAF. In October 2021, airlines committed to achieving net-zero carbon emissions by 2050, which will require significant quantities of sustainable aviation fuel (SAF) and other technological niche solutions.

However, as shown, the European Union and the United States have different policies to facilitate the transition from conventional jet fuel to SAF. The EU's Refuel EU proposal mandates aviation fuel suppliers to include a minimum percentage of SAF, including synthetic fuel, in all fuel supplied to aircraft operators at EU airports, starting in 2025, with a minimum SAF volume of 2%. The US's policies include the California Low Carbon Fuel Standard, the

Renewable Fuel Standard, and the Sustainable Skies Act, which instead of mandates provides incentives for the use of SAF. The Biden Administration also declared a goal to boost SAF production to a minimum of 3 billion gallons (9.1 million tonnes) annually by 2030. Furthermore, individual countries like France, Norway, and Sweden have already implemented SAF mandates.

Based on the interviews, the two different methods (mandates, and incentives) have their respective pros and cons. As mentioned in the interviews with the SAF producers, it is clear that mandates are the best way to reduce the risk for SAF producers and to make sure additional investments and production volumes can be met.

However, for the airlines, it gives more flexibility to work with incentives rather than mandates, due to the fact that airlines instead of being required to buy SAF from specific destinations can choose to do so if desired. However, book and claim is a solution to that, which enables airlines to purchase SAF from any geographical site, and not necessarily use it in their own planes.

Nevertheless, as pointed out in one of the airline interviews, it is difficult to be a leader in sustainability if the solutions are not available, and thus, mandates could also be seen as a good thing for airlines, since that is arguably the best way to make sure supply keeps up with the demand. Thus, both methods have their advantages and challenges. However, it became clear from the airlines perspective that when implementing mandates, the playing field should be equal. Indicating that it is not beneficial for certain countries to have higher SAF mandates than the rest, especially neighbouring countries.

Research and interviews with airlines suggest that airlines departing from countries with higher SAF mandates than the neighbouring countries would most likely result in airlines shifting their direct long-haul flights through neighbouring countries with lower SAF mandates. This would indeed not benefit the aviation industry as a whole and would increase total emissions, which is why it remains important to have a global and united perspective on SAF mandates. However, this can be challenging since the socio-technical regime is not in charge of the individual countries' mandates, and would require the landscape level to work together.

Alternative Technology	*Pros*	*Cons*
Sustainable Aviation Fuel (SAF)	● Convenient and proven technology available for all distance flights ● No major infrastructure changes required ● Different feedstocks can be used for production ● New feedstock may arise and others become more common over time, like electro-fuels ● The most likely alternative technology for long-haul flights	● Limited feedstock availability on a long-term perspective ● Emission reduction depends on the feedstock used

Hydrogen	• Possibility for short- and perhaps medium- and long-haul flights in the future • High potential and possibility for zero emissions	• Early stage and uncertain development • Requires new infrastructure and renewable electricity • Requires airplane design changes • High cost • Produced hydrogen could potentially be used for producing SAF (PtL) instead
Electric	• Optimistic and possibility for short-haul zero-emission flights	• Vastly lower energy density than conventional jet fuel • Uncertain technology and safety risks • Only short-haul flights with few passengers • Requires new infrastructure and renewable electricity

Summary of the main alternative technology qualitative findings.

DATA ANALYSIS AND INTERPRETATION

Method Of Analysis

This research consists of two analyses:

(I) quantitative evaluation of all European airlines: creation of an inventory dataset.

(II) qualitative, comparative case study analysis with included examination of the governments' characteristics, set in relation with the airlines' characteristics towards sustainability.

The first evaluation of the created quantitative dataset is carried out by using the statistical tool STATA. This program is mostly used by social scientists in order to run regression analyses because it is very well organized and offers a very clear presentation of the results which can then be interpreted according to the study. Before being able to use the statistical program, an inventory of all European airlines had to be created. This inventory consists of a large set of categories. Information collected for the inventory were worked out with a content analysis.

Selection criteria for cases:

Cases that are subject to the second, comparative case-study analysis need to fulfil certain criteria. First, a variation in the dependent variables should be given. Second, at least one, either the annual report, or the sustainability report need to be available. Third, other data sources should be available about the airlines that are subject to the analysis.

Fourth, comparable data that make clear the attitude and characteristics of the countries in which the airlines are registered need to exist for all countries included in the analysis. All four airlines need to have varying values in the number of reported items of ASI. Consequently, a variation in the first dependent variable 'extent to which an airline adopts sustainability measures' would be given (Table 3, marked in blue).

The second dependent variable is the 'publication of a sustainability report 'In order to create variation in this variable, the analysis should include two airlines that have published a sustainability report while also two airlines need to be included that have not published a sustainability report.

It is also possible to create variation in the independent variables 'national sustainability measures' and 'national sustainability measures towards the airline industry'. Using the Aviation Carbon Tax as an indication for the 'national sustainability measures towards the airline industry' two airlines should be chosen that are registered in such countries that are in Favor of the Aviation Carbon Tax, while two airlines should be chosen that are not officially in Favor of it.

Considering all these criteria, the following four full-service airlines in four different EU countries are chosen:

Country	SDG Rank	SDG Score	renewable energy consumption percentage	Full-service airline (flag carrier)	Number of reported items	Publication of sustainability report	Aviation carbon tax
Netherlands	7	71.81	6.6	KLM	6	Yes	Yes
Finland	3	79.06	41.0	Finnair	4	Yes	No
Luxembourg	17	65.96	6.4	Luxair	2	No	Yes
UK	12	70.22	10.2	British Airways	5	No	No

Comparative Case Study Analysis

As afore mentioned, the method chosen for the comparative case study analysis is a qualitative document, namely a content analysis according to Maring (2004). It is a qualitative oriented text interpretation method which is very suitable for case studies which "desire to understand complex social phenomena "(Yin, 2003, p.2). The goal is to establish new theoretical considerations related to the research question(s) with a relatively small number of texts. The core of the qualitative content analysis are categories: the relevant elements of the document texts are categorized in a repeated process of coding. Through multiple rounds of coding, meaning going through the text several times, the codes and categories are revised and improved so that the results can be interpreted correctly and, ideally, objectively.

In general, a case study is "the intensive study of a single case" (Gerring, 2012, p. 411), studying a social phenomenon or specific issue in great detail (Babbie, 2013). Qualitative approaches focus on the "interpretation of observations, for the purpose of discovering underlying meanings and patterns" (Babbie, 2013, p. 390). This is applicable to the study to be conducted as it seeks to find explanations for the variation in sustainable measures of European airlines. Interpreting the data accordingly as well as striving to detect underlying processes is of high relevance. However, instead of a single case study, this research conducts a comparative case analysis for four individual cases. Pre-determined items are examined for each of the four cases.

This way, it is possible to draw a comparison between the cases which represent the airlines. It is expected that the comparison allows to test the hypotheses and, thus, to give detailed answers to the research questions. Also, comparative case studies allow to produce generalizable knowledge (Goodrick, 2014), which is not the case for a single case study. This adds value to knowledge on another dimension as it considers the complexity of four case at once. Although a comparative case study analysis implies certain limitations such as a high resource-intensity or ambiguity about how comparable units are chosen (Abadie, et al., 2010), it is the best applicable approach to answer the research questions and to test the hypotheses due to an in- depth view into the cases (Yin, 2014).

Maring (2014) suggests specific techniques of conducting the qualitative content analysis. The Structuring – Deductive Category Assignment is the best and most suitable technique for this study because it allows to "assess the material according to certain criteria "(Maring, 2014, p. 64). Those criteria are predetermined which is why a coding guideline is strongly needed. With regard to Maring (2014), there are three steps that should be followed:

1. Explanation of categories,
2. Definition of categories,
3. Samples.

Defining the categories is important because only then the researcher knows what text elements belong to which category. Giving examples by citing text passages for each category helps to clarify the character of the categories. Rules for coding helps to avoid ambiguity of categories (Maring, 2014). Following these steps results in creating a coding scheme. In order to ensure reliably of the research, the same coding guideline and the same coding scheme is applied to all documents.

The following table depicts the applied coding scheme:

Variable	Category label	Category Explanation	Category definition	Anchor example
Use of alternative fuel	AF1	Strong positive attitude towards alternative fuel, giving examples of how it could be implemented	Very positive expressions in extensive parts of reports about e.g. . - biofuel Sustainable - aviation fuel, - renewable energy fuel/ sources	"Progress made in producing and using sustainable alternative fuels for aviation " "Air France and KLM have shown that flying on sustainable aviation fuel (SAF) can be done both safely and responsibly "
	AF2	Positive attitude towards alternative fuel	Positive expression about the use of alternative fuels, mentioning	"a new robust energy policy for substituting

			concrete other alternative fuels, e.g. – biofuel Sustainable - aviation fuel, - renewable energy fuel	fossil fuel for renewable energy sources is imperative “
	AF3	Neutral attitude towards the use of alternative fuels	Simply mentioning alternative fuels/ renewable energy, but being unclear with the formulation	“Need to increase substantially the share of renewable energy “
	AF4	Showing insufficient effort	Expression of confession that aim relating to alternative fuels was not achieved	“The ‘eco towns’ initiative of the former Labour government, promoting low carbon emissions, renewable energy (…) was substantially scaled back due to spending cuts “
CORSIA	COR 1	Strong positive attitude towards CORSIA	Strong positive expression about applying/ performing according to CORSIA, mentioning all concrete CORSIA measures, e.g. - fuel efficiency - carbon-neutral growth - CO2 emission reduction	“Aims to limit the CO2 emissions from international aviation by targeting carbon-neutral growth with an average of 1.5% annual fuel efficiency improvement by 2020“
	COR 2	Positive attitude towards CORSIA	Positive expression about CORSIA, mentioning CORSIA or one of CORSIA measures, e.g. - fuel efficiency – carbon - neutral growth - CO2 emission reduction	“The country has focused its development aid policy (…) on programs to reduce carbon emissions “

	COR 3	Showing insufficient effort towards achieving CORSIA goals	Expression of confession that aims of CORSIA were not achieved	"a civilian court recently ruled against the Dutch government for showing insufficient effort to reduce CO2-emissions "
Aviation Tax	AT 1	Negative attitude towards aviation/ environmental tax	Negative expression about aviation/environmental tax, making examples why it is bad, explaining the problems of it	"The Group is against a national air passenger tax that does not help the environment "
Other environmental related taxes	T 1	Mentioning another environmental related tax	Neutral expression about environmental related taxes	"a tax on the manufacture and import of plastic packaging "

DATA ANALYSIS

This chapter focuses on the evaluation of the quantitative dataset that was created using a documentary analysis. The dataset consists of a set of variables that are analysed for all European airlines that meet defined criteria. The program STATA is used to run the analysis 41 which results in generating a scale. This scale helps to find out more about the airlines' levels of sustainability. In the end of this chapter, the statistical results are discussed and the hypotheses 2a and 2b are tested.

Similarities and Differences between Airlines and Countries.

Comparing the reporting behaviour of the airlines and countries has resulted in the following pie charts.

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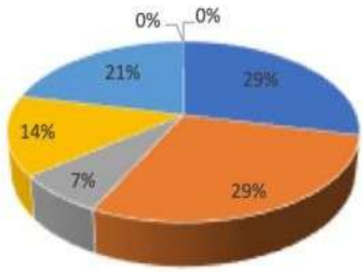
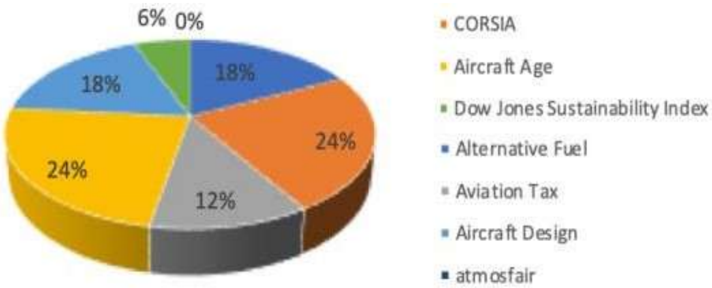


Graph 3: Country-based sustainability measures reporting



Graph 4: Airline-based sustainability measures reporting

Graph 3 depicts the seven ASI measures addressed by the four countries' reports according to their frequency. It can be seen that that the sustainability ASI measures CORSIA and alternative fuel have been addressed the most by countries. Both measures have been reported to the same percentage of 29. Comparing this with the reported sustainability measures by airlines (graph 4), it becomes noticeable that also airlines address CORSIA most. However, instead of alternative fuel, airlines address the aircraft age to the same extent as they refer to CORSIA, showing a frequency of 24 percent.

What is most interesting about the content analysis referring to the untested hypotheses is the airlines' reporting compared to the countries' reporting about the same sustainable measures. Beginning with KLM and British Airways that both expressed a negative attitude towards an air travel taxation, it can be seen that the airlines address this kind of tax although the national sustainability policy documents of 2018 have not mentioned it.

This might give a hint that airlines are thinking ahead, although the own countries in which the airlines are registered have not yet decided to establish a new binding policy.

As mentioned before, KLM is the only airline that addresses the Dow Jones Sustainability Index in order to present itself as a sustainable and good airline. It also shows the airline's proactive behaviour. Just like the other governments, the Dutch government does not see the need to address this index which might have an impact on the SDG rank. Of course, this needs to be taken into account in further research which should address the actual performance of airlines and of the countries in which the airlines are registered with reference to the selected categories of this research.

Another important point is that there is no documentation about the atmospheria Airline Index, which would have been especially interesting to investigate within national sustainability policy documents that refer to the airline, or even aviation industry. However, this also shows that the index probably is not as esteemed as other measures, for example the items of the CORSIA category.

Moreover, it is very interesting to see that there is variation in the CORSIA category, meaning that there are different expressions and attitudes about it. The Netherlands has reported on CORSIA items in a positive way, addressing the "reduction of CO2 emissions "(Ministry of Foreign Affairs of the Netherlands, 2017, p. 30) or "fuel-efficient (…) air travel "(Dutch government, 2009, p. 14). As mentioned before, KLM highlights its strong positive attitude towards CORSIA items by addressing the important aspects of the CORSIA policy all together and by highlighting them throughout the paper several times. Finland and the UK both express a positive attitude towards CORSIA as well.

However, their flag carriers Finnair and British Airways depict themselves worse than how the governments apparently see their airlines. While both countries express a positive attitude towards CORSIA, the airlines express their own insufficient effort towards achieving the CORSIA goals by confessing that, for example, "CO2 emissions from flight operations increased by 11.7 per cent from the previous year "(Finnair, 2018, p. 19).

In sum, Finnair and British Airways are more critical and less optimistic about the results and express this in their reporting.

LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

One apparent limitation of this study is the focus on sustainability reporting measured by the annual reports and sustainability reports of the year 2018 merely. Although this can be seen as an advantage of this study which highlights the clearly defined framework, the scope of this master thesis is narrowed down. Another limitation is that the quality of sustainability reporting has only been touched upon to a very restrained extent. Though the content analysis and deductive coding have both helped to determine the airlines and governments' attitudes and characteristic behaviour towards sustainable measures, the actual quality of the reports has not been analysed. This already has been mentioned by Hahn and Kohnen (2013), and, therefore, highlights the need for further research.

The examination and observations in this study might help to have a general framework that allows to analyse the reports according to predetermined variables. Moreover, this research study is limited because it solely used sustainability reports and annual reports for creating a quantitative dataset that helped to analyse the sustainable measures of European airlines. Future research might also consider interviews or questionnaires that critically scrutinize the information provided in the reports. Additionally, the research concentrates on European airlines, and, thus, the results might not be applicable to other geographic areas. Further, the findings are related to the airline/ aviation industry and, therefore, might not be generalizable for other industries.

Future research clearly should focus on the underlying economic mechanisms behind the reporting of sustainable measures in the airline industry. A longitudinal study would reveal more insight about how airlines changed their reporting behaviour throughout the years and when sustainability and environmental friendliness became important for this industry.

Further, external pressures, such as initiatives of NGOs or citizens' initiatives, should be the focus of future studies. Since this research has focused merely on the sustainability reporting, the actual sustainability performance of airlines should be considered in further research studies again.

Although previous research has already done so, today's crisis of COVID-19 might have an unforeseeable impact on the airline industry as a whole, but also on the sustainability reporting 72 of airlines. Thus, crises in general might be a very interesting topic to study regarding reporting behaviour of the main actors of the aviation industry.

CONCLUSIONS AND RECOMMENDATIONS

The aviation industry is faced with the challenge of reducing greenhouse gas (GHG) emissions and reaching net-zero by 2050. This requires a vast transformation and a phasing out of conventional jet fuel. While various stakeholders are optimistic about the industry's ability to achieve these goals, the challenges are significant. Alternative technologies need to be adopted, and clear pathways to achieving the targets must be established. The primary obstacle for each alternative solution lies in the uncertainties surrounding each innovation.

While SAF can be considered the most mature alternative technology, the feedstock availability combined with the lack of supportive policies that would make SAF more competitive to conventional jet fuel are obstacles that need to be dealt with. However, despite the anticipation of new policies, the timeline for their establishment remains unclear. As for hydrogen and electric aviation, the main challenges relate to energy density, required infrastructure, and lack of possibility for long-haul flights. While SAF is the only commercial alternative solution in the near-term, hydrogen and electric solutions are needed in order to reach net-zero by 2050.

The research aimed to explore how alternative fuels and technologies can support the aviation industry in achieving carbon neutrality. To address the high uncertainty of the aviation sector, a mixed approach combining both qualitative and quantitative studies was adopted. The analysis was framed by the MLP, a conceptual framework used to evaluate the industry as a socio-technical system. Furthermore, the study sought to answer two specific research questions. Firstly, the research aimed to explore possible ways for airlines to reduce emissions and set science-based targets in line with the Paris agreement. Secondly, the study aimed to show how different scenarios can affect the possibility for the aviation industry to follow science-based targets.

The pressure from the landscape level requires changes from the regime level, which need to implement appropriate changes in order to make it possible for niche technologies to penetrate the market and thus reduce the industry's dependability on conventional jet fuel. This could be done by introducing policies that encourage airlines to adopt more sustainable practices, such as SAF mandates or incentives for the use of alternative fuels. Additionally, airlines can adopt more sustainable practices in their operations, such as investing in fuel-efficient aircraft and optimizing flight routes. Nevertheless, environmentally friendly actions are needed in order to reach net-zero in 2050, the costs for the airlines are expected to increase, which most likely would result in increased ticket prices, in order to finance the additional costs from the alternative solutions. Moreover, in order for the aviation industry to meet environmental targets, the industry needs to work together to ensure that new technologies and required investments are utilized.

The Science-Based Targets initiative (SBTi) aims to drive corporate action on climate change and help companies set and follow their environmental targets in line with the Paris agreement. However, reaching net-zero by 2050, remains more difficult for some industries than others. Airlines are to follow the interim 1.5 co. pathway in line with the net-zero 2050 target, in order to set science-based targets. Nevertheless, the SBTi interim 1.5 co. pathway, has proven to be highly optimistic, which could result in fewer number of target submissions, as well as an increase in failed targets. While there are various ways for airlines to reduce their emissions, SAF has proven to be the main alternative solution for doing so. Thus, the SBTi 1.5 co. interim

pathway's SAF supply assumption of 51 million tonnes was challenged in order to evaluate the pathway's reliability. This has been done by comparing it to SAF supply established throughout the qualitative result, by conducting three scenarios for 2030 and 2050 respectively. The results concluded the following SAF supplies in million tonnes; 'Reference scenario 2030' (20 Mt), 'Low SAF scenario 2030' (14 Mt), and 'High SAF scenario 2030' (27 Mt). This can be compared to the 51 million tonnes assumed by the SBTi interim 1.5 co. pathway, indicating that the near-term (2030) target for the interim 1.5 co. pathway is highly optimistic and will likely not be achieved. Nevertheless, airlines may still be able to achieve their near-term targets by securing SAF supply. As for the net-zero target by 2050, the 'Reference scenario 2050' suggests that the SBTi 1.5 co. pathway's assumption of 315 million tonnes SAF could be met. However, due to the long-time horizon, there is a huge uncertainty and variation in the 'High SAF' and 'Low SAF' 2050 scenarios. While the 'High SAF scenario 2050' suggests a surplus of around 120 million tonnes, the 'Low SAF scenario 2050' suggests a deficit of around 160 million tonnes. Therefore, the results suggest that the SBTi 1.5 co. interim pathway is highly optimistic for the near-term target (2030), however, possible for the net-zero target (2050).

Overall, the thesis provides valuable insights into the challenges and opportunities for alternative solutions for aviation, and the importance for cooperation by all stakeholders, in order to reach net-zero by 2050. Moreover, it highlights the need for significant investments for alternative solutions, in order to facilitate the growth of SAF, hydrogen, and electric- powered aviation. Collaboration and innovation are the key factors for reaching environmental targets, while simultaneously balancing economic growth. Furthermore, the thesis emphasizes the importance and urgency of policies and regulations to promote the use of sustainable aviation fuels (SAF). Finally, while SBTi is an efficient way of getting airlines committed to the Paris agreement, the thesis concluded that the SBTi 1.5 co. interim pathway for airlines is highly optimistic, which highlights the urgency for the industry to accelerate its sustainability transformation.

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1. **Introduction**

- IATA – The Future of the Airline Passenger Experience — https://www.iata.org/en/publications/newsletters/2022-digital- transformation/passenger-experience/

- ACI – Global Insights on Passenger Experience — https://aci.aero/news/2022/03/08/improving-passenger-experience-through-data/

2. **Literature Review**

- ScienceDirect – Studies on Passenger Behavior and Airport Service — https://www.sciencedirect.com/search?qs=passenger+experience+airport+service
- Springer – Service Quality and Airport Satisfaction — https://link.springer.com/chapter/10.1007/978-3-030-17734-1_14
- ResearchGate – Airport Service Quality (ASQ) Framework — https://www.researchgate.net/publication/332271171_The_effect_of_airport_service_quality_dimension_on_airport_passenger_satisfaction_and_loyalty

3. **Need for the Study**

- ACI World – Airport Benchmarking Reports (why research is needed) — https://aci.aero/resources/as/
- OECD – Airport Policy and Performance Data — https://www.oecd.org/air/airports.htm

4. **Objectives of the Study**

- Emerald Insight – Passenger Loyalty and Satisfaction in Aviation — https://www.emerald.com/insight/content/doi/10.1108/JABES-05-2020- 0050/full/html
- Taylor & Francis – Quality Impact on Passenger Satisfaction — https://www.tandfonline.com/doi/full/10.1080/13032917.2020.1713801

5. **Scope of the Study**

- ACI – ASQ Program (Global Scope of Airport Studies) — https://aci.aero/programs-and-services/airport-service-quality-asq/

- ICAO – Worldwide Data on Passenger Experience
  = https://www.icao.int/sustainability/Pages/Economic-Data.aspx

6. **Research Methodology**

- Qualtrics – How to Design Passenger Surveys
  = https://www.qualtrics.com/experience-management/research/airline-passenger- survey/
- Google Scholar – Behavioural Research Techniques in Aviation
  = https://scholar.google.com/scholar?q=behavioral+research+aviation+passenger

7. **Data Collection**

- SurveyMonkey – Tips for Airport Customer Surveys
  = https://www.surveymonkey.com/mp/airline-passenger-survey-template/
- IATA – Data Collection Trends in Passenger Experience
  = https://www.iata.org/en/publications/newsletters/2023-digital/data-collection- passenger/

8. **Data Analysis**

- IBM SPSS Tutorials – Data Analysis for Survey Research
  = https://www.ibm.com/docs/en/spss-statistics/29.0.0
- ResearchGate – Analysis Methods in Airport Service Research
  = https://www.researchgate.net/publication/342313832

9. **Limitations of the Study**

- Emerald Insight – Limitations in Aviation Experience Research
  = https://www.emerald.com/insight/content/doi/10.1108/JHTT-02-2020- 0027/full/html

APPENDIX

Appendix A - Main interview questions

Main interview questions for the respective field of knowledge

1. General

- How do you envision the commercial aviation industry's use of SAF evolving over the next decade? And what factors will shape the trajectory?
- What role do you think policy and regulatory frameworks will play in promoting the adoption of SAF and other alternative solutions? And what measures do you think are necessary to support this?
- How do you vision other technological innovations, such as electric and hydrogen- powered airplanes, shaping the future of aviation? And what are the main challenges with each of them respectively?
- Do you think the aviation industry will reach net-zero by 2050?

2. SAF producers

- How do you envision the future of SAF regarding price and availability?
- How can the produced SAF volumes reach the required supply for the aviation industry? And what are the main challenges in achieving that?
- What does the future look like regarding SAF production processes, what are the main advantages and challenges with the main SAF processes?

3. Airlines

- How do you see the demand for air travel and trends evolving in the future?
- How do you envision the future alternative technologies will differ in terms of price, safety, and reliability?
- How do you see the customer's willingness to pay for more expensive sustainable solutions?

4. Aircraft producers

- How do you see the future of the commercial aviation industry moving towards 2050?

APPENDIX B - IMPORTANT QUOTES FROM THE INTERVIEWS

Important interview quotes by the multi-level perspective's three analytical levels

Quote	Why is this important?

Technological niches

"I believe that electric and hydrogen aircraft will play a significant role, particularly for shorter distances and smaller aircraft operating within hub networks. However, it is important to acknowledge certain limitations due to low energy density, such as capacity and passenger count. Consequently, in the foreseeable future, hydrogen or electric aircraft may not be suitable for long-haul flights. These technologies could potentially serve as solutions for shorter flights to smaller destinations. However, for long-haul journeys and larger aircraft, the alternatives to traditional jet fuel are currently limited." Airport Manager	SAF remains as the only alternative solution for commercial long-haul flights, as hydrogen and electric technologies have difficulties with energy density.
"It is possible for the aviation industry to reach net-zero, but there is a combination of things that need to happen at the same time. First of all, in the near-term it is essential to increase SAF production. But it will also require developments from hydrogen, electric, and potentially other solutions. So, in other words, a combination of many solutions are required in order for the aviation industry to reach net-zero by 2050." CLC Officer	The aviation industry could achieve net-zero by 2050. However, this requires vast developments from all alternative technologies. This requires the whole regime to work together, in order to meet the targets.