An exploratory evaluation of business perspectives on sustainable aviation fuels

Research on business perspective factors influencing the adoption of innovative sustainable alternatives in the aviation industry

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An exploratory evaluation of business perspectives on sustainable aviation fuels

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Executive summary

Reducing carbon emissions is one of the agreements world leaders have made at the UN climate change conference (COP26) to mitigate climate change. One of the major emitters of CO_2 is the aviation industry which keeps growing. Staples et al. (2018) state that this industry account for approximately 2.6% of the annual global CO_2 emission and probably will annually grow by 5% in the coming decades. This makes aviation, especially in the future, a major emitter of CO_2. A solution to reduce carbon emissions is to focus on Sustainable Aviation Fuels (SAF) such as biofuels or synthetic fuels or to focus on sustainable alternative technologies such as electric-powered or hydrogen-powered aircraft.

A literature review is conducted that indicates a lack of scientific knowledge regarding the social feasibility of sustainable aviation technologies in the industry. Apart from research on technology and economics, social aspects are argued relevant to explore in this socio-technical system. Followed on other research it was therefore recommended to explore factors of social feasibility such as motivation, commitment, and belief of stakeholders regarding sustainable aviation technology. This resulted in the research question: *What are the motivations, commitments, and beliefs of aviation stakeholders with respect to promising sustainable aviation technologies?* The research used a qualitative exploratory research approach using primary data collecting consisting of semi-structured interviews held with relevant stakeholders in the aviation industry. An exploratory approach will not solve the problems for sustainable technologies in aviation, but it can contribute to a better understanding of the area.

Exploratory research on the different sustainable technologies has indicated that electricity-powered aircraft will only be able to transport small numbers of people in really short distances in the coming decades. The same holds for hydrogen-powered aircraft which have a too low energy density for long-distance flights and the switching costs are high due to the requirement of new engine technology. Biofuels are currently the only commercially available sustainable fuels and are allowed to blend until 50% in current aircraft. The disadvantage is that biofuels require feedstock which will eventually become limited. Therefore, synthetic fuels based on captured CO_2 with green hydrogen has currently the most potential for aviation although it is very energy-demanding, it still requires development, and it has an expensive production process.

Based on scientific literature, a conceptual framework is constructed from innovation and business theories on why motivations, commitments, and beliefs are relevant for adoption and whether there are examples in literature. The aviation industry is according to innovation theories a socio-technical system arguing that sociological aspects are also of great importance in the development and adoption of innovative technology situated in a niche. Therefore, motivations among stakeholders for adopting innovation, commitments being made towards the technology, and shared beliefs among the industry are argued important that contribute to the sustainable transition of technology from the niche into the regime. From a business perspective that analyzed technology dominance in a battle, 10 factors are considered relevant for businesses within the aviation industry for SAFs and argue the importance of motivation, commitments, and beliefs as adoption factors. The constructed conceptual framework visualizes the coherence of the theories and presents potential adoption factors but the combination of theories lacked specification, degree of importance, and a concise list of all relevant adoption factors reflected by the industry. Therefore as a relevant scientific contribution, this research, with the use of the conceptual framework, explore and specify relevant motivations, commitments, and beliefs in the industry toward adopting sustainable aviation innovations into the current technological regime.

The interviews that have been held with stakeholders have resulted in statements regarding motivations, commitment, and beliefs wherein a saturation emerged toward multiple interesting findings. Positive motivations included regulation, sustainable awareness, future business, society and consumers, reputation, pioneering, the emergence of the market, business responsibility, and employees. These factors can all be considered accelerators of the adoption of SAF. On the other hand, aspects that demotivate the business for adoption were also determined which are the lack of business profits, financial space, certification, and proof points. Regarding the commitments, a wide variety of commitments is done towards the development of SAF, the upscaling of SAF, the development of regulation, the development of the market, setting science-based targets, and doing offtakes of SAF. Furthermore, beliefs were determined wherein all four technologies are included as well as the belief that there is simply no silver bullet for the future of aviation.

The research concludes that over the last couple of years sustainable awareness is increasing a lot and therefore it is one of the most important motivations to start adopting SAF. SAF is becoming more widely known and it is seen that momentum for sustainable transition is being built in the industry. Also, new types of motivations are specified such as the future of their business or attracting young people which can be an addition to current innovation literature. Nevertheless, the research can conclude that although the industry believes in SAF and that they are motivated by sustainable awareness, the implementation of regulations is strongly demanded to create motivation for adoption in the industry. The industry explicitly claims that they require the implementation of blending mandates that cause pressure which is needed to motivate businesses to already start adopting SAF. It shows that internal motivation like awareness is not sufficient and thus the industry demands an external motivation like regulation to give the innovation a boost. The growth of this regulatory direction with blending mandates is therefore a large difference compared to 10 years ago.

Regarding the commitments in the industry, the research specified what types of commitments are present for sustainable technology development. It gave insight that over the last years a lot of commitments in technological development is being done spread across multiple technologies whereby the main focus lies on SAF. A regulatory blending mandate is crucial and therefore the government is increasingly committed over the last couple of years to shaping this on a European level as well as evaluating a CO_2 emission limit for corporations. Trends can be seen in the increase in science-based targets being set by companies and obligatory offtakes of SAF being done. Related to this, most of the beliefs among stakeholders are in line with the exploratory research stating that biofuels are short-term solutions but synthetic fuels have the most potential in the short-medium term for aviation.

The main recommendations to put on the scientific agenda are to do additional similar research including more European countries or lay the scope on other continents. Cultures, as well as the markets, differ across the world and perhaps business perspectives could then lead to other motivations, commitments, and beliefs. The scientific base regarding these adoption factors is still lean and therefore more exploration of potential factors is advised to enlarge the scientific knowledge. Recommendations for policymakers are to lay a lot of focus on the development of regulations that stimulate the adoption of SAF. Regulations such as blending mandates and certifications are of large importance, and therefore shaping this on a European level is crucial. For the industry, this research recommends using the specifications of the adoption factors at the negotiation table or as advice for firms as a supportive base to start adopting SAF. Also recommended for the industry, is to align the beliefs among the stakeholders in the SAF technology to provide assurance for SAF producers and investors to expand the SAF production and the SAF market.

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List of Abbreviations

Table 1: List of used abbreviations

Abbreviation	**Explanation**
BtL	Biomass-to-Liquid
CO_2	Carbon Dioxide
DAC	Direct Air Capture
FAME	Fatty Acid Methyl Esters
GHG	Green House Gas
H_2	Hydrogen
HEFA	Hydro processed Esters and Fatty Acids
HVO	Hydrotreated Vegetable Oil
IEA	International Energy Agency
MLP	Multi Level Perspective
R&D	Research & Development
PtL	Power-to-Liquid
SAF	Sustainable Aviation Fuel

1. Introduction

1.1. Background

Recently in November 2021, the 26th UN climate change conference (COP26) was held in Glasgow. The aim was to reach agreements among world leaders to mitigate impacts on climate change and adhere to the Paris agreement of 2015. A crucial goal for the future is to reduce emissions and invest in renewable innovations ('COP26 Goals', 2021). One of the fields that should decrease carbon dioxide (CO_2) emissions is the commercial aviation industry. Staples et al. (2018) state that this industry account for approximately 2.6% of the annual global CO_2 emission and probably will annually grow by 5% in the coming decades. This makes aviation, especially in the future, a major emitter of CO_2. Within the aviation sector, Åkerman et al (2021) argue that long-distance travel has a larger impact than a short distance. He also argues that these long-distance travel trips probably won't decrease due to societal needs for fast travel possibilities for business or other urgent matters such as high valued cargo.

A solution to reduce carbon emissions is to focus on alternative technologies such as Sustainable Aviation Fuels (SAF) or sustainable alternative technologies. One of the options is an electricity-powered aircraft but the expectancy is that it will not be able to make long distances in the near future as well as for hydrogen-power aircraft which also requires new engine technology (Scheelhaase et al., 2019). The two major sustainable fuel technologies at this moment are biofuels and synthetic fuels which are not produced based on fossil sources (Scheelhaase et al., 2019). Decreasing the use of fossil fuels would reduce greenhouse effects and lower aviation's carbon footprint for society.

1.2. Research problem

To find the scientific knowledge gap that is important in the emergence of sustainable aviation fuels, a literature review has been conducted that will be further elaborated on in chapter 3. Based on the results of the review, several aspects can be highlighted. It can be stated that a lot of different research has been done regarding technical feasibility of several sustainable technologies. Also on economic aspects, the scientific base is widespread with different research methods to investigate the feasibility. Regarding the political feasibility, research has been done on the pros and cons of different policy solutions but they state that the solutions are yet hard to implement. Although these topics still can use more research, a specific crucial gap is not present that fits into the master's program.

The relevant gap that is worth investigating based on the literature review is the gap regarding social feasibility. Little to no research has been found on this topic related to SAF. Within social feasibility, Jiménez-Crisóstomo et al. (2021) stated that further research should be on exploring social feasibility factors such as the degree of personal motivation, commitment, and belief of stakeholders in promising technologies proposals. Analyzing this from the business perspectives of the different related stakeholders in the industry could lead to a comprehensive overview of factors that influence the adaption of sustainable aviation fuel technologies. Therefore, it is interesting to dive into the business perspectives of related companies in the aviation industry and how they stand toward the transition to sustainable fuels. Aspects such as motivation, commitment, and beliefs toward SAF are important pillars to analyzing whether the business adheres to the transition of sustainable technologies

1.3. Research objective

This research will focus from the perspective of an M.Sc. student in Complex Systems Engineering & Management on the complex socio-technical aspects that are important for sustainable aviation fuels in the future. As indicated, long-distance commercial flights are considered the most polluting travel means in society and multiple technical innovative SAF solutions are available in the transport sector. Therefore, this will be the center of this research that is linked to the first year's master's course innovations in transport (SEN174) and the goal is to explore the factors that play an important role in the adoption of sustainable fuel for the aviation industry. This research has a relevant topic for the MSc program because considering technical aspects of the innovation, the motivations, commitments, and beliefs of aviation stakeholders will be analyzed in a complex intertwined system of multiple actors for the future of sustainable aviation.

1.4. Research questions

Based on the research problem, this research will formulate an answer to the following main research question.

What are the motivations, commitments, and beliefs of aviation stakeholders with respect to promising sustainable aviation fuel technology?

To answer this question, multiple sub-questions are composed. Each sub-question aims to support the research and collect information that contributes to answering the main research question.

1. *Which SAF technologies have the most potential for the future of aviation?*

To narrow down the scope of this research, the most potential SAF technologies will be analyzed. To determine the best alternative, the pros and cons will be compared among the technologies.

2. *Why are motivations, commitments and beliefs from a business perspective important in the adoption process of new aviation technologies according to literature?*

Before reaching out to relevant stakeholders, it is useful to develop a theoretical basis regarding the adoption factors for new aviation technologies. Studies into business management and innovation management can substantiate why motivations, commitments and beliefs are important in the business perspective of the aviation industry.

3. *What are the stakeholders' views on the factors that play a role in the adoption process of sustainable aviation fuels?*

Combining the results of questions 1 and 2 will be the input to this question. The aim is to discover the views from all the related stakeholders on the factors that play a role in the adoption of new technologies for sustainable aviation.

2. Methodology

2.1. Research approach

The core of the main research question is the exploration of motivation, commitment, and belief toward SAF for the stakeholders in the aviation industry. Therefore, this research has the objective to conceptualize what the standpoints of these different actors are regarding the promising sustainable fuels technologies. To get an answer to this question, an exploratory research approach is used. An exploratory research approach does not have the goal to have a final conclusive solution to the problem, but to explore and having a better understanding of the problem at the end (Dudovskiy, 2018). Therefore this is a suited approach to use in this research since it will not solve the problem of adopting sustainable fuels in aviation, but it can contribute to a better understanding of the area.

For the data collection, this research has a qualitative research method to explore and understand the factors in the business perspectives regarding SAF of the involved stakeholders (Creswell, 2009). The method involves interviews with airlines, experts on SAF, possible start-ups, and other related stakeholders that can give insights into perspectives of SAF transition. The aim is then to establish an overview of aspects in business perspectives that influence the adaption of sustainable fuels in aviation.

2.1.1. Advantages and limitations

The main advantage of this research approach is that it remains flexible and can adapt within the research. When crucial statements are discovered, the following interviewees can be asked their opinion about this. Also, this approach could lead to a wide range of different subjective opinions between stakeholder groups that result in a comprehensive overview. For example, airlines probably have different business perspectives regarding SAF compared to start-ups. The exploratory base of this approach will also lay the effective groundwork for further studies to implement solutions for discovered problems (Dudovskiy, 2018).

Limitations to conducting this kind of research are that due to conducting interviews, often a limited number of samples are used. This could lead to not covering the whole target group and therefore is the research not generalizable for a wider population. (Dudovskiy, 2018).

2.2. Research Methods

2.2.1. Data collection methods

This research consists of an exploratory qualitative research approach to find the factors in the business perspectives regarding SAF of the involved stakeholders. To gather this data, the following methods were used to collect the data.

Literature review

The first part of this research consisted of a literature research into the different SAF technologies to compare and appoint the most potential. Also, two open interviews are held with experts in the field of aviation technologies. This is done to require extra information with their expertise and knowledge regarding the different SAF technologies compared to scientific literature. Following this, a literature review is done to search for the knowledge gap in the current literature that forms the basis for the main research question. With the use of the search engine Scopus, the review is conducted regarding SAF technologies. Based on what came out of the technology comparison, the search command was made more specific from ‘Sustainable Aviation Fuels’ to ‘Synthetic fuels in aviation’.

Theory review

The second part of the analysis required data based on scientific literature. Doing research into theories substantiate the motivation, commitment and belief factors from a business perspective why they play a role in the adoption process of new technologies. The aim is to search within theories from business management and innovation management studies to argue why they are important factors as well as potential factor examples for the research. An example is the multi-level perspective which maps socio-technological transitions of potential new innovations on different levels in a socio-technical system (Geels, 2002). An interesting business theory can be regarding the factors in a competing technology battle to determine the winner by Van de Kaa et al. (2011).

The benefit of using this method is that it can use a lot of already existing knowledge discovered by others and by combining this data the answer to the second part of the analysis can be found. A downside of gathering data in this way is that it has probably no concise answer and that often perspectives differ amongst each other as well as the moment of research in time. Nevertheless, combining multiple different inputs can lead to a useful substantiation of the adoption factors for new technologies.

Interview data

Followed on the theory review, the next part of the research consisted of the collection of empirical data regarding stakeholders' views on the factors that play a role in the adoption process of sustainable aviation fuels. For the exploration of views on the factors, non-documented data is collected given by the relevant stakeholders in the aviation industry. This data is more opinion-based but includes the expertise of the stakeholders in aviation which makes it very valuable.

To gather data, the aim was to conduct approximately 10 to 15 interviews with relevant stakeholders from different backgrounds. A quick and general stakeholder analysis is done to get a broad view on the relevant stakeholders in the industry. The goal was to aim at these stakeholder groups and try to connect to relevant people. Due to the global character of aviation, the collection of data could be very broad. Therefore, to keep the research feasible, the primary scope was on European stakeholders. The stakeholder groups that were aimed at are airlines, aircraft manufacturers, airports, aviation engineering experts, government, oil/SAF producers, consultants, environmental organizations, and start-ups. With these groups, it was expected to get a broad view of the aviation industry. Via contacting people through LinkedIn, personal contacts, and e-mails, 14 stakeholders participated in an interview. Table 2 presents the interviewed people anonymized under their stakeholder group.

Table 2: Interviews

Interview ID	Stakeholder
1	Expert 1
2	Expert 2
3	SAF producer 1
4	Airline 1
5	Start-up 1
6	Airport 1
7	Start-up 2
8	SAF producer 2
9	Airline 2
10	Consultant 1
11	Aircraft manufacturer 1
12	Airline 3
13	Government 1
14	SAF producer 3

This research has an exploratory approach, therefore the questions were semi-structured (Creswell, 2009). The reason for a semi-structure in the questions is because the factors for new technology adoption were used as input for these interviews. These factors were used as a thread in the questions to help the respondents cover all the relevant areas as well as keep the interviewer within the parameters of the aim of the study. Nevertheless, the purpose was to remain flexible and to open the floor for the interviewed actor to give his or her view on factors that are considered important by the persuasion of sustainable aviation fuels. The interview guide can be found in appendix A. Limitations to this research method are that conducting the interviews is often time-consuming for the researcher as well as for the interviewee as it cost relatively some time. For this reason, the interview data is not extra verified by the interviewees after transcription by sending it back and let them check their statements. Also, as mentioned before, this method has often a limited number of samples which leads to a lack of generalization over a larger group (Dudovskiy, 2018)

A data gathering method wherein a limited number of respondents may suffice for research is the Delphi method. This is a method that uses an iterative process to collect data from multiple experts in the field by conducting several rounds of interviews allowing participants to refine their views throughout the progress of the research group. Through the statistical aggregation of the group's data, quantitative analysis and interpretation are possible (Skulmoski et al, 2007). However, for this research, it is chosen not to use this method. The downside of the Delphi method is the fulfilment of multiple rounds of interviews which is time-consuming for the stakeholders. The risk appears that they won't participate in multiple rounds which will result in a malfunctioning data gathering method. Therefore, this method is deliberately not chosen to use.

Another method that could be incorporated into the data gathering is the Q-sort method which is a methodology that let respondents rank a sample of opinions or statements. This is a combination of a data gathering and data analysis tool which involves highlighting correlations between variables in the sample (Jedeloo & van Staa, 2009). However, this research has an exploratory nature which ought to find these statements and not yet compare them to find the correlations. Therefore, also this method is left out.

2.2.2. Data analysis methods

When all the data is compiled from all parts of the research, the results can be used for the analysis. Multiple data analysis tools were used to construct answers to the research question, the following were used in this research.

Theory review analysis

The review collected a bundle of research data from business and innovation frameworks. To analyze these, a conceptual framework was created that visualizes the role and relation between the frameworks regarding the motivation, commitment, and beliefs. Examples of these factors serve as the basis for the interviews to discover the views among stakeholders in the industry regarding the adoption of new promising technologies.

Qualitative interview analysis tools

To analyze and interpret the large amount of data gathered from the interviews, a software-based tool was used. The program Atlas.ti is a tool to easily analyse and structure qualitative data such as views and opinions given by the actors. The program can help to sort the number of similar statements and views into distinct categories that result from the data or from previously determined categories in the literature. From the categories, the program can produce visualizations such as frequency distribution graphs and word clouds for a systemic analysis. (ATLAS.ti Scientific Software Development GmbH, n.d.) The following steps were done in the program to analyze the data:

Step 1; The first step in this analysis was to map and use the adoption factors substantiated by business management and innovation management theories in the first part of the research. These factors were appointed as codes in the program to create multiple structured groups. The codes in the program got a specific colour

Step 2; The second step is that all the interviews were analyzed and the views and statements that ought to be interesting for the factor group were highlighted with the corresponding code colour which created multiple groups of a bundled number of views and statements relating to an adoption factor to create an answer to what the stakeholders' views are on the adoption factors.

Step 3; The third step was when the statements were structured and bundled into groups, the analysis for a discussion of factors took place. This was a discussion of the statements that adheres to answering the main research question by for example using the frequency distribution of mentioned statements per factor category as well as the degree of strong argumentation within the factor groups.

2.3. Method layout

To give a clear visual overview of the structure and the logical process flow of this method, a research flow diagram is presented. This is done to structure and sharpen the project, get an idea of the required research activities, and find the balance in the research load of the sub-questions. The diagram is presented in figure 1.

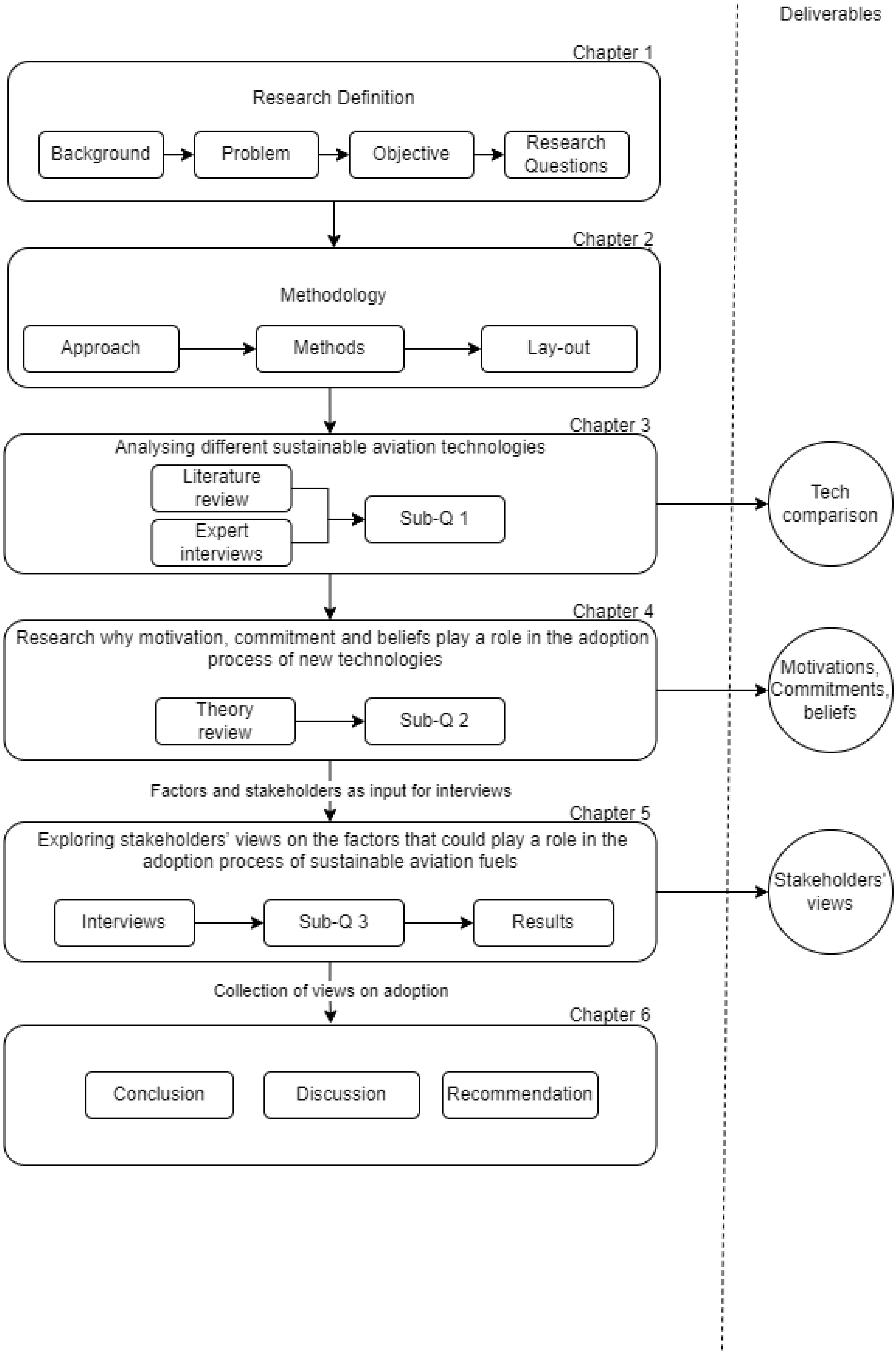

Figure 1: Research flow diagram

3. Review technologies and literature

3.1. Sustainable Aviation technologies

This part of the chapter gives an overview of the available technologies that are possibilities for the aviation industry to mitigate carbon emissions. This answers the first sub-question regarding which SAF or technology has the most potential for the future of aviation. It is the first step in answering the main research question because it is relevant to know all aspects of the technologies for further research. Therefore, positive and negative aspects are highlighted for the technologies to find out which technologies have the most potential for the future of sustainable aviation. Most information is gathered from the publication of the International Energy Agency (IEA) regarding energy technology perspectives in 2020. This recent publication examines over 800 technology options that could adhere to reaching worldwide net-zero emissions in 2050. Furthermore, two exploratory open interviews are held with experts in the field of aviation technologies. This is done to require extra information with their expertise and knowledge regarding the different SAF technologies compared to scientific literature. Expert 1 is an aerospace engineer and professor at the TU Delft. Expert 2 is a professor of Sustainable Transport and Tourism at Breda University of Applied Sciences with a background in aircraft engineering. At the end of this part, table 3 presents all the positive and negative aspects of technology.

3.1.1. The potential technologies for aircraft

The current type of fuel that is used in the whole aviation industry is jet kerosine which is produced from fossil oils. The consumption of oil by aviation accounts for approximately 7% of the global demand for oils. This consumption needs to be reduced since it causes nearly 3% of the whole energy sector's carbon emission through combustion in 2019 (International Energy Agency, 2021). Although the substitution of fossil fuels is very important, energy efficiency is also a crucial technological driver in the reduction of the consumption of fuels and therewith the emission of carbons. As already mentioned, four available technologies could potentially adhere to reducing these emissions. These are electric-powered aircraft, biofuels, hydrogen, and aircraft that fly on synthetic fuels.

3.1.1.1. Electric powered aircrafts

The electrification of vehicles is increasing a lot and is seen all around in society. Electric bikes, scooters, and steps are more prominent in the street view, public busses are becoming more and more electric, and especially electric cars are winning ground with car manufacturers shifting to electric or for example Tesla which has designed a very competitive electric car for the market. Nevertheless, these vehicles only operate on very short distances which is not viable for the aviation industry. According to the IEA (2021), the battery technologies are very unlikely to ever provide an energy density sufficient enough for an electric aircraft that is viable to fly on mid-range and long-range flights. Even with major breakthroughs in battery technologies, it is expected to remain unviable. Also, the aircraft need radical changes according to expert 1 because of the weight of the battery.

Flights on short ranges such as regional jets may have a small potential but then the currently available batteries would have to increase at least threefold. Prototypes like these are in the early stage planned for 2030. These short ranges cover only 100 to 250 km and can only transport less than 10 people according to expert 1. Even if the technology improves significantly, it then still has to compete with the high-speed rail that is already available on these short distances. According to the IEA, the only role electric aircraft could then have is on routes were building an expensive rail infrastructure is not viable or the travel volume is very low.

3.1.1.2. Biofuels

Liquid fuels made of sustainable biomass could potentially become an alternative for the aviation industry that lowers the carbon emission of flying. Already projects are present with liquid bio kerosine to be blended with conventional fuels. This is already legal and technically allowed up until 50% of the blending according to Expert 1 but it currently only accounts for 0.01% of total aviation fuel consumption (IEA, 2021). At this development stage of bio-kerosine, blending is the most viable option but the aim is to create drop-in biofuels which can completely substitute conventional kerosine. One of the main benefits of biofuel technologies is that in neither blending nor drop-in fuels the vehicle technology has to be changed (IEA, 2021). Also, expert 1 claims that biofuels are a relatively cheap solution although it is still two to three times more expensive than conventional kerosene.

Within biofuels, there is a difference between conventional biofuels and advanced biofuels which leads to different kinds of concerns. Conventional biofuels or 'pure biofuels', as Expert 2 names them, consist of fatty acid methyl esters (FAME) which are derived from oilseed crops such as soybean oil. The fact that these fuels are produced from crops will eventually lead to competition with agricultural land. The demand the aviation industry will require can't be met without hindering the food industry as well as the amount of land use that is required for these crops (IEA, 2021).

Advanced biofuels or second-generation biofuels are fuels that are produced on a higher technical level and are technically feasible to be drop-in fuels. The aim is to have a high share of waste and residues used instead of oils and fats from crops. The current dominant advanced biofuel can use the same process technologies as conventional biofuel which are Hydrotreated vegetable oil (HVO) and Hydro processed esters and fatty acids (HEFA) but which are then both mainly produced from waste and residues. The next generation that is becoming close to commercialization is Biomass-to-liquid (BTL) which is a fuel that is thermochemically produced (IEA, 2021). The main benefit of this technique is that it can use a wider range of biomass inputs such as woody biomass, energy crops cultivated on marginal land, municipal solid waste, and residues from agriculture and forestry (IEA, 2021).

Although advanced biofuels give the impression that they could be a good solution to substitute for burning fossil kerosine and mitigate the CO_2 emission, it comes with some negative aspects. According to expert 2, the process of turning biomass into usable biofuels is a very complex process as well as the fact that it is in terms of energy conservation a very inefficient technique. Biomass consists of relatively low energy density causing the need for a lot of feedstock and processing this into useable fuel leads to hardly a positive energy balance. Also, the processing energy needs to be sustainable which is still not always the case today according to expert 2, otherwise, it is still not genuinely carbon neutral. Also in terms of genuine carbon neutrality, expert 2 points to the fact that using municipal waste causes to process also plastics and other oil products. Although this gives these products a second purpose and it is an increase in efficiency, it is not a zero-emission solution to burn fossil oils in used plastics.

Even though using residues from agriculture and woody biomass could be a zero-emission solution, it has also constraints that using this biomass can disturb biodiversity according to expert 2. All this biomass is biological material that contributes to the fertility of the soil that has to be taken into account. Also, the use of waste for biofuel could not be a long-term solution due to the goal of becoming a circular economy in the Paris agreement by reducing waste by society (expert 1). If a circular economy will be created, there will be no residues to produce biofuels with and then competition starts with the food industry and agricultural lands.

Concluding on biofuels, it could be in the short term for blending or drop-in fuels a feasible solution for aviation. Nevertheless, in the long term, it will encounter a lot of problems that could not be overcome while remaining a zero-emission solution.

3.1.1.3. Hydrogen

Through water electrolysis, water is split with an electrochemical process into hydrogen and oxygen. This hydrogen consists of energy that then can be used as a fuel alternative without any involvement of carbon resources (IEA, 2021). This makes the use of hydrogen an excellent zero-emission alternative for vehicles, nevertheless, it encounters some enormous problems for the aviation industry.

First of all, the production of hydrogen is a very energy-demanding process. This energy should be renewable to remain zero-emission but this lacks in availability and causes hydrogen to be much more expensive than conventional kerosene. Second, the energy density of hydrogen is very low which makes it hard to transport and store. Expert 2 argues that much more space is needed in an aircraft to store the hydrogen which will go at the expense of passengers or cargo. Third, and most problematic aspect of hydrogen for aviation is that hydrogen is not compatible with the current aircraft technologies. It is not a drop-in fuel, but completely new engines need to be built. This comes at an enormous expense as well as the fact that the life expectancies of aircraft are 20 to 25 years which will take a long time to completely replace the current fleet (expert 1 &2). Also, the development of these hydrogen aircraft is still in the prototype phase which leads to, according to expert 1, the potential large implementation of these aircraft after 2040.

3.1.1.4. Synthetic fuels

Synthetic fuels are made from hydrogen, CO_2 captured from the air, and renewable electricity. Using sustainable electricity, the captured CO_2 is converted together with hydrogen into syngas. From this composite gas, a usable fuel can be made for aviation. These form the basis of synthetic kerosene. After mixing with fossil fuel or eventually being used as a drop-in fuel, it can be used in all types of aircraft (IEA, 2021).

Capturing CO_2 directly from the atmosphere through direct air capture (DAC) technologies makes this fuel a technology that can close natural loops. Capturing the carbon, converting it into kerosine, burning it in the aircraft, and eventually capturing again the carbon results in an ongoing circle that emits zero-emission in the short term (Expert 2). Also, the fact that it can be used as a blending or a drop-in fuel is one of the benefits of this technology because this gives it broad compatibility with existing aircraft technology and infrastructure. Therefore, airlines such as KLM are already experimenting with blending synthetic fuels with conventional fuels on 0,5% of their flights at the moment (Expert 1). Furthermore, compared to a sole hydrogen alternative, it has a higher volumetric energy density which makes it easier to store and transport as well as less fuel volume is needed in the aircraft itself to fly distances.

All together it gives the impression that it could be a very good solution, however, the biggest problem at this moment is the use of energy in the production of synthetic fuel. Capturing carbon from the atmosphere, producing hydrogen, and processing the mixture into a usable kerosene for an aircraft requires a significant amount of electricity which should be renewable (Expert 1&2; IEA, 2021) According to expert 2 and the IEA, the current production efficiency of the factories is quite low because only between 20% to 40% of the energy input ends up in the final liquid kerosene product. Along with the expected growth of aviation in the future, this will require an enormous amount of sustainably generated energy while the competition for renewable energy also keeps growing. Due to this high energy use, synthetic fuels become up to six times more expensive than conventional kerosine with the current oil prices.

Nevertheless, both experts ought synthetic fuels as the best alternative in the medium-long run to be able to meet the goal of becoming carbon-neutral in 2050. It is environmentally a zero-emission technique and the drop-in technology prevents major changes in aircraft and infrastructure. Renewable energy generation remains a big problem, but expecting maybe advances and declining costs by for example solar energy in the desert would decrease the problem according to expert 2. At this moment, aviation has no better alternative than synthetic fuels with high energy demand.

Table 3: Summary positive & negative aspects of technologies (IEA, 2021)

Technology	Positive aspect	Negative aspect
Electric	- Could be of potential on routes where building a rail infrastructure is expensive or travel volumes are too low for a rail	- Current designs are unlikely to ever provide sufficient density to make electric planes viable for mid-and long-range flights - Uncertainty about technology, first prototypes planned for 2030 - Currently available battery technology would have to increase at least threefold to support short flights - Current batteries are too heavy for long-distance flights - Developments in advanced battery chemistries are crucial - Unviable for the mid-range and long-range flight
Biofuels	- Can provide a lower carbon alternative because it is derived from sustainable biomass instead of conventional fossil oil for kerosene - Liquid biofuels can be blended with conventional fuels and Drop-in biofuels can completely replace conventional fuels - Blending is legal till 50% and more could be possible - Requires no change in aircraft technology or infrastructure - Conventional biofuels are produced from oilseed crops such as soybean - BTL uses woody biomass, energy crops cultivated on marginal land, municipal solid waste, residues from agriculture, and forestry - BTL, HVO, and HEFA are technically drop-in biofuels. - BTL, HVO, and HEFA can mitigate sustainability concerns due to using waste by giving it a second purpose - Biofuels are relatively cheapest	- Competition agricultural land - Land use can negatively affect biodiversity and soil fertility - Growth is constrained by the limited availability of waste and residue - Circular economy could hinder the availability of waste - Complex process to turn biomass into usable biofuels - Inefficient energy conservation lead to a lot of feedstock needed - Clean energy needs to be used during the entire feedstock, otherwise not CO neutral - Use of waste could lead to burning plastics and other fossil oils - Cost of producing biofuels is strongly influenced by feedstock costs - Aviation got hindered by competition from other sectors using sustainable biomass - For commercialization, a stronger policy and regulatory push are needed
Hydrogen	- Produced from water makes it a zero-emission solution	- Energy demanding process - Currently much more expensive than conventional kerosene

	- When costs for renewable energy decline, renewed interest could emerge. - Technically feasible - Basis for synthetic fuels	- Low volumetric energy density of hydrogen - Incompatible with current aircraft technology and infrastructure - High transition costs - Prototype phase, potential full implementation after 2040
Synthetic e-fuels	- Higher volumetric energy density - Storage and transport is easier compared to hydrogen - Aircraft need less fuel by volume - Broad compatibility with the existing fossil fuel-based infrastructure - Multiple technological possibilities exist to produce synthetic fuels - Close natural loop for zero-emission - Could play an important role in the energy trade - Technically feasible - Can make an important contribution in the long term till 2050 to reducing CO_2 emissions - Produced from captured CO_2 and sustainable hydrogen - Able to blend or as a drop-in fuel	- Carbon neutrality requires only direct air capture (DAC), no other carbon sources - Production requires significant amounts of electricity - Between 20% to 40% of the energy input ends up in the final liquid product - Production costs are influenced by current fossil fuels prices in combination with CO_2 capture ability - Currently multiple times more expensive than conventional kerosene with current oil prices - Policy intervention is required

3.2. Knowledge gap in literature

Following on the previous technical part it became clear that SAF including biofuels and synthetic fuels are currently most developed whereby synthetic fuels are ought to be the best alternative in the medium-long run. Based on that, this part searches for the scientific knowledge gap and the main research question that fits to this gap regarding SAF. Therefore, a literature review has been conducted. The aim was to scope down and exactly determine the scientific research problem. To analyze the resulting literature, an innovation framework is presented that is useful to determine the problem.

3.2.1. Method of literature review

The literature review was conducted with the use of Scopus to find scientific literature regarding innovations in SAF. With the use of the search command 'Sustainable Aviation Fuels', too many results were presented that gave no clear overview of relevant literature for this review. Therefore, the search command was made more specific to most potential SAF: 'Synthetic fuels in aviation' which led to 427 hits. Since this topic is present in a lot of research, the limitation was set to the publication years 2021 and 2022. This is done because most recently conducted research gives the most actual and representative results of the current situation. After scanning the papers, 4 different categories regarding the e-fuels could be generalized while other papers are left out due to irrelevance for this research. These categories were the technical functioning, the production, the economic lifecycle, and health effects on workers. With backward 'snowballing' two extra papers regarding political barriers to synthetic fuels were found. Backward 'snowballing' is an extra method that looks in the citations of the papers to find related papers to the topic.

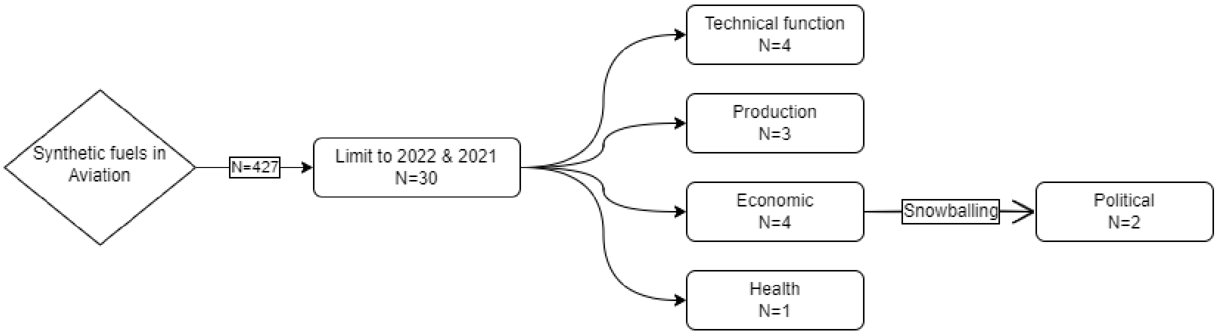

Figure 2: visualization of the method

3.2.2. Innovation framework

To get a clear overview of the papers and analyze them to find a research gap, the political economy model of transport innovations by Feitelson & Salomon (2004) is used. This model is a theoretical lens that helps determine the level of analytical sufficiency regarding the adoption of transport innovations. The model tries to answer the question of why some innovations are adopted and others fail in the process. According to Feitelson & Salomon (2004), an innovation has to be determined feasible in technical-, economic -, social-, and political aspects. Considering these criteria, the papers are analyzed whether synthetic fuels in aviation are sufficiently researched or if a gap exists.

3.2.3. Overview of literature

Table 4: Overview of the literature

Authors	Year	Category
Ugbeh Johnson et al.	2022	Technical
Boehm et al.	2021	Technical
Białecki et al.	2021	Technical
Nadiri et al.	2021	Technical
Petersen et al.	2021	Economic
Kulanovic & Nordensvärd	2021	Political
Karanikas et al.	2021	Health
Becattini et al.	2021	Economic
Meurer & Kern.	2021	Production
Gössling et al.	2021	Economic
Jiménez-Crisóstomo et al.	2021	Economic
Schäppi et al.	2021	Production
Magone et al.	2021	Production
Scheelhaase et al.	2019	Political

3.2.4. Review results

This section consists of an overview of the literature structured according to the four criteria of Feitelson & Salomon (2004). First, to have a general look at table 4, it becomes clear that research especially has been done regarding the technological functioning and the economics of synthetic fuels. This is still a general result of the review, therefore the next part will analyze how much research has been done per criteria.

Technological feasibility

Table 5: Papers regarding technological feasibility

Authors	Year	Main topic
Ugbeh Johnson et al.	2022	Review regarding problems of ice formation in sustainable jet fuels
Boehm et al.	2021	Models on performance properties of synthetic fuel and different compositions
Białecki et al.	2021	Comparison of synthetic fuel blends and its performance
Nadiri et al.	2021	Burning properties of propanol isomers and butanol isomers as jet e-fuels were investigated in a high-pressure shock tube.
Meurer & Kern.	2021	Development of a synthetic fuel production plant and challenges compared to current approaches
Schäppi et al.	2021	Possible approach of producing synthetic fuels by demonstrating thermochemical solar fuel production chain
Magone et al.	2021	Comparative life-cycle assessment between the production of traditional aviation fuel and synthetic fuel

Within the scope of the literature review, most of the literature dives into the technical feasibility of sustainable synthetic fuels. In the review, a distinction between functionality and production was made, but they all fall under the scope of whether the use of synthetic fuels is technically feasible. Boehm et al. (2021), Białecki et al. (2021), and Nadiri et al. (2021) researched the performance of synthetic fuels and stated that different compositions of fuel blends could give a promising performance for the aviation industry. A performance challenge as indicated by Ugbeh Johnson et al. (2022) whereby synthetic fuels could be more affected by icing, but with certain adjustments, this could be solved.

Regarding the production of synthetic fuels, Meurer & Kern (2021), Schäppi et al. (2021), and Magone et al. (2021) researched the technical level. Synthetic fuel plants can be constructed based on existing technologies, but another possible approach is to use a thermochemical solar fuel production chain. Also, a life-cycle analysis was done that concluded that synthetic fuel production requires roughly the same amount of energy as crude oil refining, but the shift to more renewable resources makes it a better alternative.

Economic feasibility

Table 6: Papers regarding the economic feasibility

Authors	Year	Main topic
Petersen et al.	2021	Techno-economic comparison of SAF in bio-ethanol and synthetic fuels
Becattini et al.	2021	Techno-Economic scenario comparison wherein 1 scenario consists of synthetic jet fuels that are produced by CO_2 as feedstock
Gössling et al.	2021	Economic analysis on synthetic fuels that can phase out fossil fuels
Jiménez-Crisóstomo et al.	2021	Socio-Economic factors that cause an unchanged air transport energy paradigm.

In terms of economic feasibility, multiple research has been done with different methods. Petersen et al. (2021) did a comparative analysis between fuels where was stated that synthetic fuels have the highest efficiency and cost the least per liter. Also, Becattini et al. (2021) validated this claim as the best scenario compared to others. Gössling et al. (2021) made an economic analysis wherein he ought it possible for fossil fuels to be phased out by synthetic fuels in 2050. Lastly, Jiménez-Crisóstomo et al. (2021) argue that a lot of economic factors like market constraints and compliance with safety requirements will cause an unchanged energy paradigm but promising technologies such as e-fuels could make a difference.

Social feasibility

Table 7: Papers regarding social feasibility

Authors	Year	Main topic
Karanikas et al.	2021	Health risks for workers related to exposure of conventional and alternative fuels
Jiménez-Crisóstomo et al.	2021	Socio-Economic factors that cause an unchanged air transport energy paradigm.

The feasibility of innovation from a social feasibility perspective is when the majority of the society votes in favor and is likely to support the innovation according to Feitelson & Salomon (2004). Karanikas et al. (2021) did not analyze this societal majority but they analysed the health risks of workers exposed to alternative fuels. He states that workers still experience health risks regarding alternative fuels and more research has to be done. Therefore, workers as part of society should be included in the feasibility of the innovation.

Jiménez-Crisóstomo et al. (2021) did a socio-economic analysis as presented in the previous part. They discuss constraints regarding the energy paradigm in aviation, but they close with *"Further research should be pursued to explore the real adherence of sector stakeholders to sustainability institutional policies and goals as well as their degree of personal motivation, commitment, and belief to pursue the new industry technology proposals*." (Jiménez-Crisóstomo et al., 2021) They state that motivations and commitments from aviation stakeholders towards long-term sustainable technology developments as well as their beliefs in the technological success will be fundamental factors for the development in scenarios of future sustainable aviation. However, this is a issue that lacks scientific exploration on these social feasibility factors in the literature according to them. Therefore, this strongly presents a gap in the social feasibility of the technology.

Political feasibility

Table 8: Papers regarding political feasibility

Authors	Year	Main topic
Kulanovic & Nordensvärd	2021	Sweden case-study on political lock-in regarding sustainable aviation
Scheelhaase et al.	2019	Barriers of synthetic fuels and related political measures

The Swedish case study by Kulanovic & Nordensvärd (2021) displays several political lock-ins for sustainable innovation. Regarding sustainable fuels, problems arise with minimal support structures for e-fuels and the fact that conventional kerosene still is tax-free. Scheelhaase et al. (2019) also investigated the barriers for synthetic fuels and highlighted the same fact that commercial aviation remains free of any climate-related taxes. Policy solutions could be a compulsory blending quota of the fuel or the introduction of green certificates, but changes in policies are considered hard due to the international character of aviation.

3.2.5. Review discussion

Reflecting on the results that have been presented in the previous section, several aspects can be highlighted. It can be stated that a lot of different research has been done regarding technical feasibility. Also on economic aspects, the scientific base is widespread with different research methods. Regarding the political feasibility, research has been done on the pros and cons of different policy solutions but they state that the solutions are yet hard to implement. Although these topics still can use more research, a specific crucial gap is not present that fits into the master's program.

The interesting gap that is worth investigating is the gap regarding factors within social feasibility. Little to no research has been found on this issue while Jiménez-Crisóstomo et al. (2021) state that motivation, commitment and belief of sector stakeholders will be of fundamental importance in the development of future sustainable aviation scenarios. Therefore they stated that further research should be on exploring the factors of motivation, commitment, and belief of stakeholders in promising technologies. Analyzing this from the business perspectives of the different related stakeholders in the industry could lead to a comprehensive overview of factors that influence the adaption of sustainable fuel technologies.

4. Theoretical frameworks

In this chapter, the answer to the second sub-question will be presented regarding why motivation, commitments, and beliefs are important factors from a business perspective in the adoption process of new aviation technologies according to literature. A combination of frameworks from business theories and innovation theories will be presented that serve as building blocks and give potential examples of the importance of motivation, commitment, and beliefs. This forms the theoretical basis for the main research question wherein this research may enrich the academic knowledge regarding these factors. The frameworks that will be presented are selected due to the expertise of the researcher in innovation sciences. The knowledge and usability of these frameworks are known and therefore considered important and selected for this research. At the end of the chapter, a conceptual framework is presented in figure 4 that visualizes the role and relation between the frameworks regarding the motivation, commitment, and beliefs which form the basis for the interviews to discover the views in the industry regarding technological transition

The adoption of innovative aviation technology is not only bound to the development of the technology itself but literature argues that it is also bound to multiple sociological factors. Technology actors often tend to focus on optimizing the technology side first while neglecting important social aspects of the technology (Schot & Geels, 2008). The technology has to go through a transition that Geels (2002) describes as a technological transformation of the way societal functions are accomplished. Societal functions are aspects such as nourishment, housing, and, relevant for this case, transportation. This technological transition is not only involving the change in the technology itself, it is also subjected to wider aspects of the society such as infrastructure, regulations, user practices, and industrial and social networks. To fulfill a certain societal function, it has to configure these aspects of society to create a technological change. This configuration is often not easy to be done because it involves changes in routines and patterns of behaviors in organizations. To set this configuration in motion, the specification of their motivations and beliefs are essential to explore. Especially in large embedded companies such as airlines, patterns are deeply rooted over a long time and therefore not easy to change. To create a technological transition that works, these changes need to be embedded into the organization environment and the business perspectives of the large companies. This means that the adoption of innovative technology such as SAF is not only situated in a technical environment but in a socio-technical environment consisting of technical as well as sociological conditions that are often deeply rooted in the business (Geels, 2002).

Socio-technological transitions such as new aviation technologies are due to the involvement of multiple actors often a complex and continuing process. With that, Geels (2011) argues that transitions towards sustainable technology have some different aspects for businesses compared to historical transitions relevant for this case. The first aspect is that historical transitions were innovations for exploring new technologies to create new commercial opportunities for entrepreneurs as motivation. On the other hand, SAF is a sustainable innovation which is goal-oriented with the purpose to adhere to environmental problems such as mitigating the emissions of CO_2 in aviation. The large implication with this is that sustainable transitions adhere to a collective good which is not very attractive for private business actors and could be a demotivation to focus on it. Regarding the transition toward sustainable aviation fuels, the goal is to fly with zero emissions instead of developing a new commercial opportunity. The framework argues that commitments of public authorities can play an important role to create more incentives for these organizations with certain measures, but also the sustainable awareness of becoming net-zero among businesses keeps growing over time as a motivation factor.

The second aspect of sustainable transitions compared to historical ones that could be important factors for this research are that often a sustainable solution does not offer the same user benefits due to the collective nature, the price is higher and the performance is lower than the current technology. As indicated in the previous chapter of the comparison between different SAF technologies, all potential technologies are much more expensive than fossil kerosene which makes it less beneficial for the airline industry. Also, the performance is lower than conventional kerosene in terms of energy use because the production of each of the potential fuel technologies costs a large amount of energy to produce it. Therefore, these aspects may be important for stakeholders that make it hard for sustainable technology such as these fuels to compete against and replace the established technology. A factor such as regulatory intervention could for example be needed to support the change.

The third difference is an aspect relating to large domains such as agri-food, energy, and in this case transport where the transition toward sustainability is most needed. In the aviation domain, often large embedded firms such as oil companies are situated that possess complementary assets, as Geels (2011) calls it, consisting of networks, distribution channels, expertise with test trials, and the capability of large-scale manufacturing. It is therefore hard for small-scale entrepreneurs without these assets to compete with the incumbent firms although small-scale entrepreneurs often develop environmental innovations first. As mentioned, an example from the aviation industry is large oil companies that are dominant in supplying the airlines with fossil fuels with all their available resources. It is therefore hard for the smaller companies that focus on new sustainable fuels to compete against these giants in the market. The framework, therefore, argues that it is relevant to explore how these large firms can get involved, change their business perspective, become committed, and use their resources to support environmental innovations to accelerate the development and let it break into the current systems.

4.1. Multi-level perspective

Following the aspects of sustainable transitions, it is relevant to conceptualize patterns within socio-technological transitions to explore other sociological adoption factors. Geels (2002) has constructed an integrative evolutionary theory called the Multi-Level Perspective (MLP). It is an analytical framework combining concepts from different fields such as neo-institutional theory, structuration theory, evolutionary economics, and science and technology studies. This results in a view on socio-technological transitions in a non-linear process interplaying between levels which all consist of factors that influences innovation adoption. The landscape level, the regime level, and the niche level are three analytical levels that reflect heterogeneous configurations of elements in for example the aviation industry. The lower the level, the less stable actors and the degree of alignments are present.

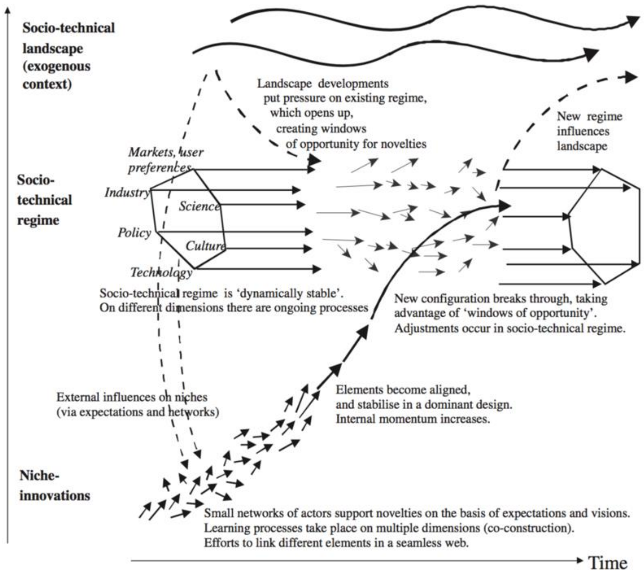

Figure 3: The Multi-Level Perspective (Geels, 2011)

Landscape

The socio-technological landscape is the upper level reflecting the wider context which consists of deeply structured trends. It is a concept that involves macro-economic patterns, demographical trends, societal values, and political ideologies. These concepts are often conservative which usually change slowly and need a long period for adaption. These deeply structured trends can be therefore an important factor in technology adoption since conservatism could demotivate technological change. On the other hand, landscape developments can put pressure on the lower levels in need of innovative technological change. Environmental problems and the need for carbon reduction are examples of the landscape level putting pressure on the aviation industry to motivate and commit to sustainable new technologies such as SAFs.

Regime

The socio-technical regime is the middle level of the perspective which forms the 'profound structure' in the existing socio-technical system which accounts for its stability in it. The regime involves a set of semi-coherent rules among linked actors across multiple social groups that organize the activities that take place in the system. Often are these rules hard to change because they are deeply structured in the current system. Changes by innovation in these rules of the current system are often small and incremental and therefore the regime is generally bounded by a lock-in of the system. Examples of these rules are competencies and capabilities, user practices and lifestyles, regulations and institutional arrangements, and legally binding contracts but apart from these, the framework argues that also shared beliefs and cognitive routines are crucial in this system. Therefore, the exploration of the beliefs in the industry is assumed necessary for the system how to adopt new technology. Regarding the aviation industry, in this case, the current dominant regime is the use of fossil fuels for all aircraft. This is a technology that is deeply structured in the industry by practices of aircraft technology, capabilities to produce cheap kerosene, regulations that support the use of kerosene, and routines by airlines to buy kerosene.

Niche

The lowest level in the perspective with the least stability is the level for niche innovations wherein SAF technology is situated. Niches are described as small environments with a protective character that gives opportunities for innovations to develop. It can respond to special demands and can experiment in small markets or research and development laboratories. Actors that are present in a niche are often start-ups, entrepreneurs, or spinoffs working on a promising radical new technology aiming to enter the current regime or even replace it. However, this is a hard trajectory due to the lock-ins of the current regime like the dominance of conventional kerosene and the fact that the innovation might not be able to match the current rules in place such as the shared beliefs. Nevertheless, to create technological transitions, niches are essential as building blocks for systemic change. The framework argues that exploring adoption factors for the transition between the niche and the regime is important such as what the industry drives or demotivates to start replacing fossil kerosene with sustainable aviation fuels.

Regarding these adoption factors the niche innovation environment consists of three core internal processes that can be distinguished that are crucial for the development of a niche and the potential replacement of the current dominant technology (Schot & Geels, 2008). These processes can be strongly related to and argue why the motivations, commitments, and beliefs of stakeholders are important for technology adoption. First, the articulation of expectations and visions are important drivers that provide direction for innovation activities. To have aligned expectations among business stakeholders is important to move in the same direction which can lead to an increase in motivation for developing the innovation as well as more commitment to trying to breakthrough in the current regime. Also, a shared vision or belief in the innovation adheres to moving together in the right direction for the innovation. Having the same expectations and visions among the businesses often leads to better cooperation or the will to invest in new technologies. As already mentioned in the part regarding technological transitions, SAF technologies have fewer commercial benefits compared to the current fossil fuels so there has to be a collective vision of the sustainable benefits of SAF technologies to be able to compete with fossil fuels. The second process within the niche is the building of social networks. This is a process that contributes to the availability of important resources such as people, expertise, and money for the development and adoption of SAF technologies. The facilitation of interactions between stakeholders can lead to more of these resources and can create the articulation of the various view and beliefs that broaden cognitive frames. The third process is the learning process consisting of multiple dimensions that contributes to the internal niche development which can all influence on the motivation for that development. These are technical design, market and user preferences, infrastructure networks, industry networks, policies and regulations, environmental and societal effects, and cultural meanings.

The development of the niche and the ability to gain momentum to enter the regime is dependent on a stable technology configuration resulting from aligned learning processes and a large network of interacting business actors. Commitments toward this configuration can then result in the creation of resources and shared visions, beliefs, and expectations. However, the framework does not specify these commitments and therefore it is relevant to explore these as well as to specify the motivations for adoption of these niches to gain momentum.

4.2. Functions of an innovation system

The central idea of the multi-level perspective regarding the importance of certain processes within a niche that are determinants for the success of innovation toward the current technological regime is comparable with the theory of Hekkert et al (2007) and relevant for the development and adoption of sustainable technologies such as SAF. This theory uses the term innovation system as a heuristic approach to map all important socio-technological aspects that are needed to be able to create technological change in society. The innovation systems (IS) approach is relevant for this case because it has the central idea that innovation and the diffusion of technology is not only an individual process but rather a collective one. It involves individual technological development but it is also dependent on a large social network of public and private sectors steering activities and creating interactions that lead to the entrance, import, and diffusion of new technologies in the society. To map key activities, describe the process, and explain shifts for technological change in innovation systems, Hekkert (2007) has proposed a set of functions that are considered important: entrepreneurial activities, knowledge development, knowledge diffusion through networks, the guidance of the search, market formation, resource mobilization, and creation of legitimacy. These seven functions can be used as building blocks to the aspects of motivation, commitment, and belief that are needed among actors for innovation and thus sustainable aviation fuel breakthroughs.

The first function regards entrepreneurial activities of the industry that are crucial for the functioning of an innovation system. The theory states the importance of commitments toward activities of entrepreneurs that can create new business opportunities for developing innovation by testing potential new knowledge, using networks, or discovering potential new markets. These activities can come from new entrants such as start-ups but also from established firms who aim to change (parts of) their business strategy for new developments and adopt new technologies. Excellent examples of this are companies that shift their strategy toward adopting more sustainable solutions. Within the whole industry but also within the company itself, commitments are important to shift these activities into sustainability such as airlines that want to adopt alternative sustainable fuels.

Knowledge development within the industry is the second function of an innovation system and is crucial for every innovation process. Every innovation starts with a small idea that is then enlarged with knowledge through learning into a business opportunity. Therefore, the development of knowledge forms one of the basic aspects of the success of an innovation. R&D projects, patents, and R&D investments are the three often important indicators to indicate the development of this function. Following knowledge development, the third function is the diffusion of this knowledge through networks. Information exchange is essential for innovations to develop, to create a support base, and to create a shared belief. If the knowledge regarding a potentially useful innovation spreads through networks, governments can make supportive policy decisions, competition increases leading to faster development and markets grow. To create this knowledge development and diffuse it for SAF technologies, the aviation industry has to make active commitments in R&D programs for sustainable fuels and invest in them to be able to compete with fossil fuels. Also, the consideration of a sustainable innovation needs a collective support network from the businesses to be able to develop.

The fourth function is the guidance of the search meaning that in an innovation system decisions have to be made towards a certain technological option. Often multiple options exist that cause a spread of focus on technologies which could lead to an insufficient amount of resources for the individual option. The search and exploration for the best options have therefore to be guided at a certain moment in the same direction of beliefs to develop and adopt the best innovation option. This guidance is not only affected solely by the market or influence from the government, it is also an interacting process of the industry between many actors exchanging expectations, ideas, and beliefs. Therefore, this function can be interesting to explore in the case of SAF because at this moment multiple options are available. It could be depended on the beliefs of relevant stakeholders which adoption pathway is going to be taken in SAF technologies.

Market formation is the fifth function and should make a runway for new technologies to be able to develop and compete against embedded technologies. It is comparable with the forming of niche markets in the MLP because innovation needs protective spaces to develop and grow. New technologies performing often less than current technologies, especially in sustainable innovations. Therefore, it is important to make commitments to form markets for these new technologies creating competitive advantages through for example tax stimulation. Hekkert (2007) gives an example of tax exemption for biofuels in Germany which led to a creation of a biofuel market while in the Netherlands a large market is lacking due to no tax exemption. Similar to the aviation industry, such tax structure could be an important motivation to form a market. Following the formation of markets, the mobilization of resources is also a basic principle of the development of innovation and the creation of knowledge. The resources such as financial capital as well as human capital are crucial aspects in motivations for the activities needed for innovation development. Available funds, investors, and a network of knowledgeable people are needed for a company as well as the innovation system as a whole to compete against the current technology.

The last function proposed by Hekkert (2007) is the creation of legitimacy and counteracting the resistance to change. Especially in sustainable innovation systems is this an important function to take into account because the support base for environmental-friendly technologies is still often too low. By putting new technology on the agenda, lobbying for relevant resources, and trying to form new markets, they try to create legitimacy for the adoption of an innovation trajectory. One of the basics for creating legitimacy for new technology is how society takes a stand towards it and whether they resist change. Therefore, it is relevant to lobby within the society on how their beliefs are towards the adoption of new technology and try to discover how legitimacy can be created. The same goes for SAF because legitimacy is needed to create a wider support base for sustainable fuels, and discovering visions toward the technology plays a crucial role.

4.3. Standard battle in technology dominance

The perspective from a business point that is considered regarding new aviation technologies is the perspective of a standard battle by Van de Kaa et al. (2011). This is a perspective that refers to a battle between two (or more) technologies (in the paper referred to as format) that are competing against each other to become the dominant technology in the market. Competing technologies for adoption are also the core of this research wherein sustainable aviation fuel technologies are competing with the current dominant fossil kerosene for aircraft. Therefore, factors from this perspective can be considered relevant to explore for the motivation, commitment and beliefs towards SAF technologies by businesses.

Van der Kaa et al. (2011) performed a comprehensive literature study wherein they analyzed 127 publications in which factors were mentioned regarding a battle between technologies towards dominance in the markets. They summed up the factors to a total of 29 that could potentially determine the winner of the technology battle. In the paper, the factors are divided into two categories: Firm-level factors and environmental factors. The firm-level factors consist of 23 factors that can be influenced by the firm itself and these factors are then divided into 4 categories namely: characteristics of the format supporter, characteristics of the format, format support strategy, and other stakeholders. The environmental factors are more focused on the whole industry such as the aviation industry wherein a specific firm has barely any influence on the factor. Market characteristics are the only group in this category. Regarding this research, the aim is to find factors that argue the importance of motivations, commitments and beliefs in the adoption and not the battle in general of the development of the technology. Therefore, not all 29 factors will be relevant for this study as well as the fact that the factors of Van der Kaa et al. (2011) are for a technology battle general and not specified for aviation technologies. Nevertheless, a selection of factors from this perspective can be of great importance to the factors from a business perspective for the adoption of sustainable aviation fuel technologies.

The first group of factors is the format supporter and which dives into the development of the technology itself and the support around it. One of the factors is financial strength which is defined as the financial condition of the company and its future prospects considering investments and helping start-ups. The technology comparison of the previous chapter outlined that costs of the SAFs are high at this moment and therefore businesses need to be financially healthy to be able to endure longer periods of high prices for new technology meaning that the financial factors could play an important role in motivation toward sustainable aviation technologies. The second factor in this group that can be important for the adoption is the brand reputation and credibility. The reputation of a company or the credibility of the technology can play a significant role in the selection of users to choose the technology. In the case of sustainable technologies such as SAF, the public can attach more value to sustainable fuels than to conventional fuels which will lead to positive impacts and an increase in adoption.

The second group of factors is regarding the characteristics of the format laying focus on the superiority of the technology compared to others. Regarding sustainable technologies such as SAFs, it will be hard to become superior to the current fossil technologies due to their lower performance and efficiency. Nevertheless, a factor that can be important for adoption choices is the compatibility of the technology. The compatibility concerns the ability to fit with current interrelated entities to be able to function together. As an example already mentioned, drop-in fuels are probably much more attractive for the businesses being able to function with current aircraft technology. Therefore, the compatibility of SAF could be a motivator for businesses for adoption.

The third group is the format support strategy and this is more related to the social feasibility of SAF as determined interesting in the previous chapter. It focuses more on the support of the technology from the firm to help it become more successful. A factor such as pricing strategy refers to commitments made to create market share for the technology. This could be important whether airlines are willing to and be able to calculate the high costs of SAF into the ticket prices. This is also related to the important factor of commitment of the firm to the technology. The factor of commitment refers to the importance of sufficient support and attention obtained from each of the actors in the industry for the technology. Especially in the early stage of the technology, the costs are high and returns are low which is the same for SAF technologies. In nine studies found by Van der Kaa et al. (2011) they state that a positive relationship is suggested between technology dominance and commitment. Therefore, it is for this research relevant to explore whether businesses are committed to sustainable aviation fuels to be able to become successful.

The last group on the firm level is the group of other stakeholders which could influence the technology dominance and some of them could also be related to aviation technology adoption. Especially the factor regulator is important in the technology adoption for businesses because the regulator can support technology or decrease the attractiveness of the other. As already mentioned in the previous chapter based on literature, often a policy intervention or a regulatory push is needed to motivate companies for SAF technology to be able to compete with current fossil fuels. Therefore, the role of the regulator could be an important factor for businesses adopting new aviation technology. Also, the factor of the network of stakeholders is in line with the importance of a shared belief in the industry because a wide network of stakeholders supporting the technology could help develop a support base and attract other stakeholders to adopt the technology, and create a higher chance of achieving dominance.

Following on firm-level factors, environmental factors could also be interesting aspects to consider for business in the aviation industry. The first one is the uncertainty in the market about whether technology can succeed compared to the potential risks. This influences the likelihood of adoption and the speed of adoption of the technology by the industry. SAF technology is still in the early stages of development and a lot of uncertainties are still present, therefore it could lead to a lack of motivation for companies to focus on SAF. Also, the rate of change is important, because beliefs in new technology often require time for change. This makes it difficult for new generation aviation technology to penetrate the market although this is also related to stakeholders who are restrained from focussing on and adopting these new technologies. Lastly, the switching costs for new technology could be an important aspect of motivation for SAF technology adoption. The fact that aircraft last long and are very expensive causes high switching costs when new technology is needed for SAF. As mentioned, bio and synthetic kerosene are more expensive than conventional kerosene and hydrogen requires new types of engines which cause switching costs and thus may hinder the businesses from adopting these types of SAF.

Every group of factors on either firm-level or environmental level consists of aspects that are probably important for the adoption of aviation fuel technologies in general. The 29 factors from Van de Kaa et al. (2011)focused on only technology dominance in a battle, but these 10 mentioned argue the importance for motivations, commitments and beliefs by aviation stakeholders. For clarity, these are the factors summed up:

1. Financial strength
2. Brand reputation and credibility
3. Compatibility
4. Pricing strategy
5. Commitment
6. Regulator
7. Network of stakeholders
8. Uncertainty in the market
9. Rate of change
10. Switching costs

4.4. Conceptual framework

As a concluding answer to the second sub-question regarding why motivation, commitments, and beliefs are important factors from a business perspective, multiple different frameworks are used to argue this. With these frameworks, a conceptual model is created in figure 4 that shows the relevance and coherence of the theories as building blocks for this research. The basis is the multi-level perspective wherein the focus lies on the transition between the niche toward the regime. For a niche to enter the regime, a lot of different adoption factors could play a role, but this framework visualizes especially the relevance of motivation, commitment, and beliefs in the industry to accelerate the adoption of a niche such as SAF into the regime.

The framework is based on the fact that new aviation technologies can be considered innovations for the industry and Geels (2002) argues that innovations develop in a socio-technological environment consisting of technological factors as well as sociological factors for adoption. These sociological factors such as motivation, commitments, and beliefs are considered relevant for transitioning the new technology into the society for common usage. However, sustainable transitions such as SAF experience different sociological aspects compared to historical transitions which indicate examples of adoption factors. The increase of sustainable awareness may be a motivation to accelerate the transition or commitments by public authorities to develop regulations to support niche transition.

Furthermore, the niche level itself consists of internal processes contributing to the success of the new technology and argues the relevance of the adoption factors among stakeholders. The commitments toward the configuration of shared expectations and an aligned social network may be relevant adoption factors for the industry.

In addition to these factors, the heuristic approach of innovation systems with multiple functions to map socio-technological factors by Hekkert (2007) argue the relevance and potential adoption factors. The focus lies on the development of an innovation, but the functions also reflect important factors for the adoption of new technology. Entrepreneurial activities, for example, require commitments for a strategy change in established firms before sustainable innovations can be adopted. Also, the guidance of the search argues the importance of the beliefs of relevant stakeholders that have to be explored and guided in the same direction for the right innovation adoption. Lastly, legitimacy has to be created for the adoption of new technologies. To do this, lobbying is needed in society and collect beliefs about new technologies on how to create more support base.

Furthermore, Van der Kaa et al. (2011) have constructed factors that are considered important in a technology battle toward becoming the dominant technology in the market. From this list of factors, 10 of them are considered relevant for businesses within the aviation industry for SAFs and argue the importance of motivation, commitments, and beliefs as adoption factors. Some of the examples are reputation as motivation for adoption, high switching costs as demotivation, and an aligned network that contributes to a shared belief for the acceleration of the niche adoption.

In a conclusion based on the combination of the perspectives in the conceptual framework, it can be stated that both innovation and business frameworks confirm that motivations, commitments, and beliefs are relevant adoption factors. However, although several potential examples are presented, the frameworks lack specification, the degree of importance and a concise list of all relevant adoption factors reflected by the industry. Therefore, this research will as a relevant scientific contribution, with the use of this conceptual framework, explore and specify relevant motivations, commitments, and beliefs in the industry toward adopting sustainable aviation innovations into the current technological regime.

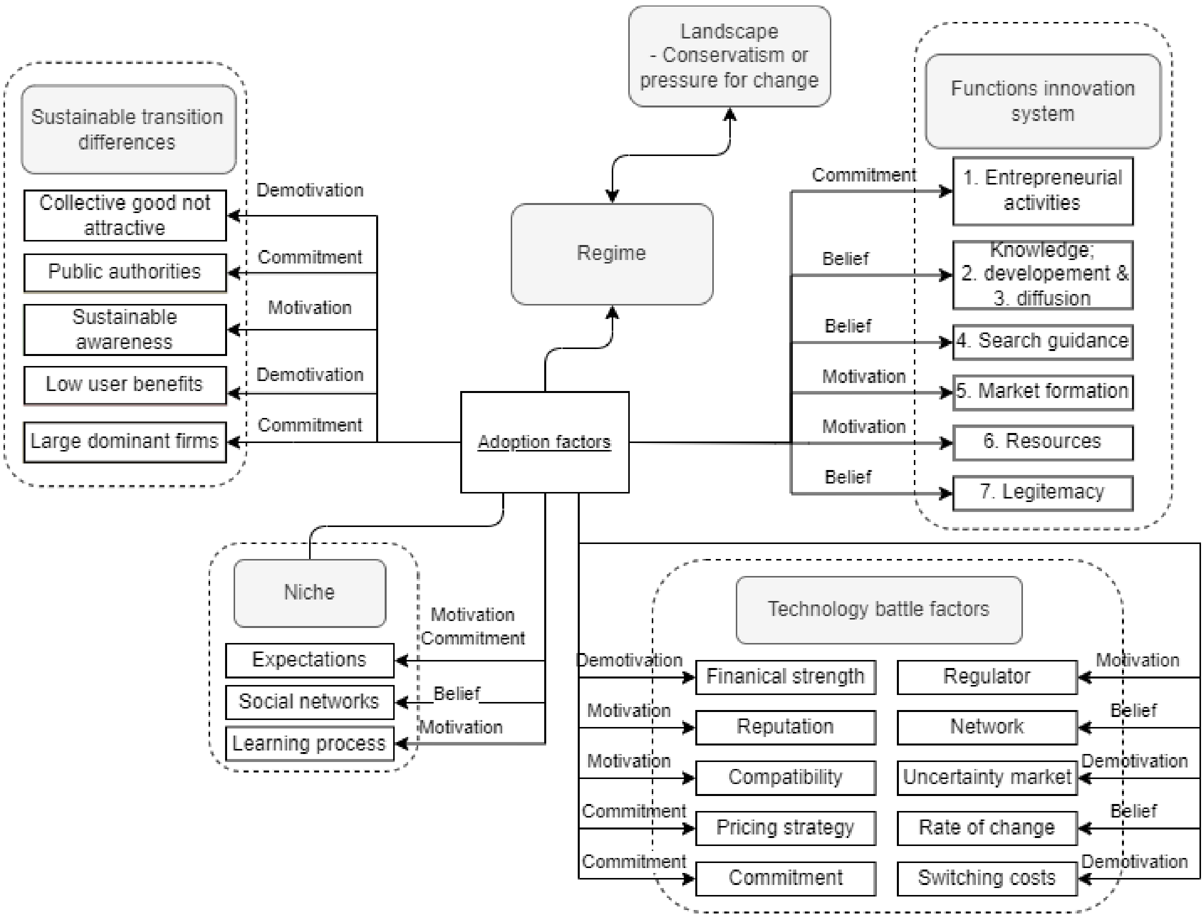

Figure 4: Conceptual framework

5. Results

This chapter presents the stakeholders' views on the adoption of sustainable aviation fuels, related to sub-question 3. The 14 semi-structured interviews that are held with stakeholders with different backgrounds have resulted in a large number of findings. As explained in the methodology section, the interviews are coded with the software-based tool Atlas.ti by structuring a number of similar statements in categorical groups for analysis. Within these groups, a saturation of aspects emerged due to similar statements mentioned across multiple interviews. Each group show a saturation and will further elaborate the statements in the following chapter. Motivation, commitments, and beliefs are the major groups, but within these groups, sub-categories are presented that have resulted from the conceptual framework and the interviews. Atlas.ti created figures 4, 19, 26, and 33 which show the sub-categories with the corresponding frequency of statements in the interviews. Every sub-category begins with a Atlas.ti visualization of the frequency distribution of statements among stakeholders followed by the elaboration of the sub-category. After these parts, the views on the 10 adoption factors from the literature are elaborated which show quite some overlap with the motivation, commitment, and beliefs. As of last, the main differences over the last 10 years towards sustainable aviation are being presented to show the sustainable transition.

5.1. Motivation

According to the stakeholders, motivation for the adoption of sustainable aviation fuels considers a wide range of aspects that are deemed important. Within the code-group of motivation, a distinction has been made between positive and negative motivation which ought to accelerate or decelerate the adoption of SAF. Furthermore, statements are grouped into certain motivation categories that originated from the conceptual framework and the views of the stakeholders which can be seen in figure 5. These groups are elaborated on further in detail, first the positive motivations and followed by the negative ones.

Figure 5: Motivation categories with corresponding statement frequencies

5.1.1. Positive motivation

Sustainable awareness

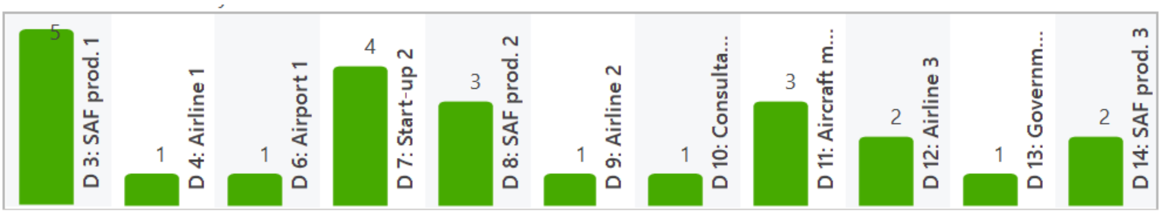

Figure 6: Frequency distribution of mentioning sustainable awareness

The most obvious and therewith repeatedly mentioned motivation among the stakeholders is sustainable awareness in the aviation sector. Every stakeholder has mentioned the increasing awareness of sustainability as an incentive for exploring the possibilities of adopting sustainable aviation fuels. Everybody agrees that the aviation industry has a large impact on global carbon emissions and that these emissions will become larger along with the growing aviation industry market. Therefore, the carbon emitted by the aviation industry needs to be reduced otherwise they become the largest polluting industry in the world.

Airline 1 states that he is personally very worried regarding the climate on earth and that we are already very late in taking action. Airline 3 states: "*Climate change is real. It is happening, and we have* *to do our bit to minimize or eliminate our impact on it. That's the first and foremost motivation*". We really have to act now as soon as possible and the awareness is slowly growing that it should not be voluntary intent but that sustainability is a very serious condition to act on right now rather sooner than later[5]. Following this, SAF producer 1 notices that the business environment is changing especially among corporates that have increased attention to the importance of becoming sustainable in their business operations. Multiple views validate this increased awareness by considering it as a license to operate to do something with the climate in constructing sustainability principles, setting certain emission targets, and making plans to make their business as sustainable as possible. In the end, the ultimate goal is to have net-zero airlines and have a net-zero industry but that is going to take a lot according to multiple views.

Regulation

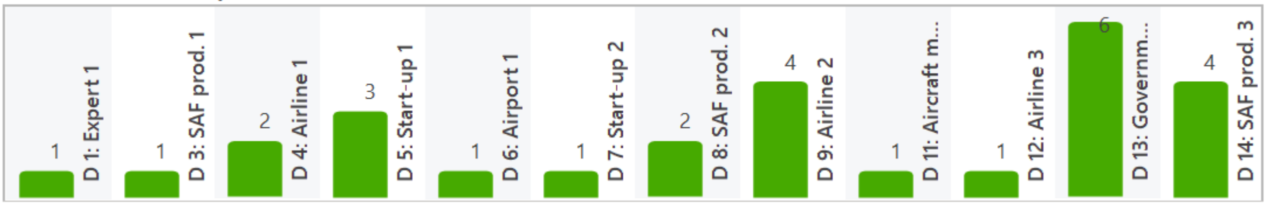

Figure 7: Frequency distribution of mentioning regulation

Regulation is the other frequently mentioned motivation for the adoption of SAF technologies according to the respondents. Although the awareness of sustainability is growing, the adoption of sustainable fuel is still a voluntary incentive causing the adoption of only small proportions, and not every corporate takes action for including it in their business plan[7,9]. To increase the adoption, more is expected from the regulators to stimulate and even obligate the use of sustainable fuels by corporates. Start-ups 1 & 2 claim it as crucial importance for the motivation and support for the SAF sector. The Paris agreement forms the basis of sustainability goals and motivation for SAF adoption, but it is still not enough to motivate the whole industry. The EU Commission has presented a set of legislative proposals in July 2021 called the "Fit for 55" package which includes, among others, policies for transport to reach the European Green Deal's objective of reducing at least 55% greenhouse gas emissions by 2030 compared to 1990[1,8,9,12]. Regarding the aviation industry, this policy includes blending mandates which means that conventional fuels must be blended with a certain percentage of sustainable fuels. Some of the stakeholders have mentioned certain percentages, but figure 5 presents all the ascending mixtures that are included in the fit for 55 packages (*Fit for 55 and ReFuelEU Aviation*, 2021). To add to this, some countries have higher goals than Europe prescribes whereby Airline 2 and government 1 indicate the action plan of the Netherlands which includes a blending mandate of 14% already in 2030.

	2025	2030	2035	2040	2045	2050
Percentage of SAF used in air transport:	2%	5%	20%	32%	38%	63%
Of which: sub-mandate Synthetic fuels (or e-fuels):	-	0.7%	5%	8%	11%	28%

*Figure 8: Blending mandates fit for 55 (*Fit for 55 and ReFuelEU Aviation*, 2021)*

Numerous stakeholders have indicated that the requirement from the regulators with blending mandates put pressure and will create an increased motivation from businesses to lay more focus on the use of SAF. Start-up 1 pinpoints that this system may be not considered an own incentive but the mandates every 5 years cause a deadline to fulfill and so it can be seen that it motivates corporates to already start taking action earlier towards that mandate. It is considered a quite robust way to stimulate the market, but many people see it as an important motivator whereby it gets things started which is a positive development.

Society and Consumer

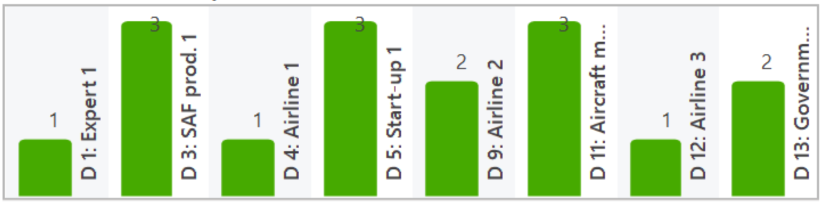

Figure 9: Frequency distribution of mentioning society and consumer

Airline 3: "*Consumers and society want to see that companies are doing what they need to do to minimize their impact on the climate both now and also to invest in the future*. Society and the consumer, the people who in the end do use SAF, are also considered important motivators in the business perspective views. The emergence of societal pressure and the public perception of sustainability is causing a serious push in motivating businesses to decrease their emissions. All three airlines notice that customers who fly with their airline are increasingly demanding to fly more sustainably by flying on SAF. Not only customers that fly occasionally on vacation are becoming more aware of sustainability but also corporates that see sustainable flying as an important way to create a sustainable business environment[5,11]. This causes the airlines to want to adhere to these demands and it motivates their businesses to focus more on SAF and make it more possible to fly on SAF for their customer.

Following on the airline demand, the SAF producers notice that a few years ago they had to push themselves to get people involved in SAF but confirm that nowadays a change can be noticed that a growing number of airlines want to buy SAF[3]. Also, the aircraft manufacturer notices a demand from airlines incentivizing them to focus on technology development to make it possible to blend SAF safely on higher levels in aircraft[11]. These are then also, on another level of consumer demand, positive motivations for these businesses to accelerate sustainable development.

Reputation

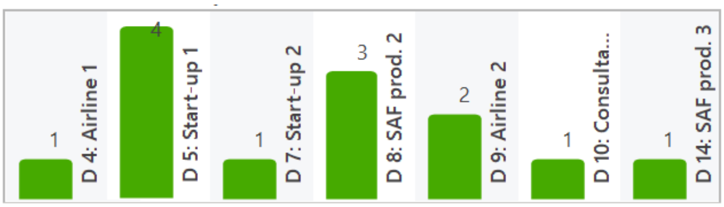

Figure 10: Frequency distribution of mentioning reputation

Reputation is also a mentioned motivator from a business perspective as an incentive to focus on SAF technologies. It is related to the previous motivator of society and consumers, but that motivator lays more focus on demand, whereas reputation lays more focus on the profiling of the businesses themselves. As a corporate business, it is getting more and more important to profile yourself as someone who delivers a contribution to the environment by decreasing your carbon emissions. Therefore, this is seen as a motivation among companies to focus on SAF to increase their sustainable reputation[7,14]. Start-up 1 sees indeed that an increasing amount of companies consider it important to publicly show that they are working on something related to sustainability and therefore invest in biofuel or synthetic fuel start-ups. Consultant 1 sees this also as a potential positive domino effect whereby the more companies publicly show a good reputation of sustainability, others may get motivated and follow in these tracks.

The other side of this story is of course the presentation of a good reputation while this is not true or only partially true. Airline 2 states that he recently read that a budget airline has announced that they will blend 35% of all their outgoing flights from a specific airport. However, they have only a few flights from that airport which makes it according to him only smart publicity. The same goes for a cargo company that announced their usage of SAF in tonnes which made it look like a large amount. However, it is only the way of presentation because recalculating this number to the consumption on an annual basis makes it almost nothing. Lastly, SAF producer 2 states that two other cargo companies publicly announced that they will fly on 30% SAF in 2030 which is a positive incentive but he claims that it is also a strong marketing and reputation strategy[8]. All these statements in the publicity can be questioned, but on the other hand, it can also be solely a smart way of marketing because Airline 2 also states that as a company you should be careful because you don't want the definite mark of greenwashing or insincerity.

Future business

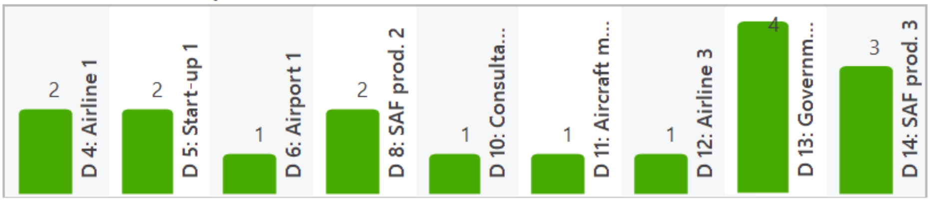

Figure 11: Frequency distribution of mentioning future business

Airline 1: "*I think that aviation needs to accelerate enormously in order not to become a bankrupt branch of sport in the future*" This is something that also drives the motivation within the aviation industry namely that you have to keep innovating for the future of your business because otherwise, you will run out of it. Therefore, start-up 1 sees that companies recognize that innovating and investing in new sustainable technologies such as SAF is crucial for the future of their business and the sector as a whole. When you as a company won't fit in a sustainable future, there won't be a right and ability to exist according to Airport 1 and government 1. Related to this aspect, aircraft manufacturer 1 states that about 4 years ago they had a board meeting wherein it became very clear that they seriously had to do something toward sustainability for their future and created plans to do so. Also SAF producer 2 states "*We have always achieved a fairly strong position in kerosene and kerosene sales, both production and trading, and in principle, we want to continue to maintain that position now with SAF*". With this, across different companies, the motivation of having a business in the future also motivates them to focus on SAF. SAF producer 3: "*Oil is something that will run out and the dependence on oil and gas is not a good thing so we have to look for an alternative*"

Pioneering

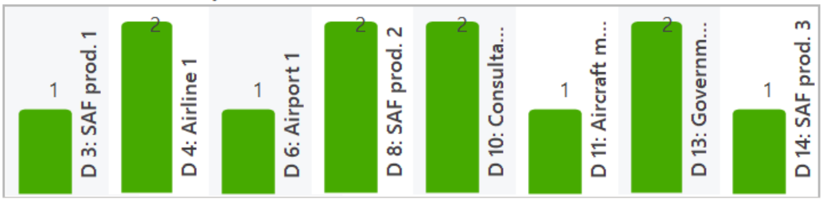

Figure 12: Frequency distribution of mentioning pioneering

Pioneering is also a form of positive motivation for companies to focus on sustainable aviation technologies. This has some overlap with the motivation for future business but pioneering focus more on the drive of being the front runner and wanting to be an early adaptor for the industry. SAF producer 3 created a SAF department 13 years ago and the company of SAF producer 1 was founded 12 years ago with the incentive to create a market for SAF as one of the first. Airline 1 also claims that pioneering is one of their motivations to focus on SAF as a core of their sustainable business mission to "*not just transporting people from A to B, as we always did, but working on a new way of transport by connecting people and connecting cultures. We want to anticipate on the sustainable future*". Already exploring opportunities as a pioneer and contributing to the future of the zero-emission aviation industry is also a motivation mentioned by consultant 1. Most of the airlines in Scandinavian countries are pioneers but pioneering is not for everyone[11]. Nevertheless, for some companies is this an important motivation.

Business responsibility

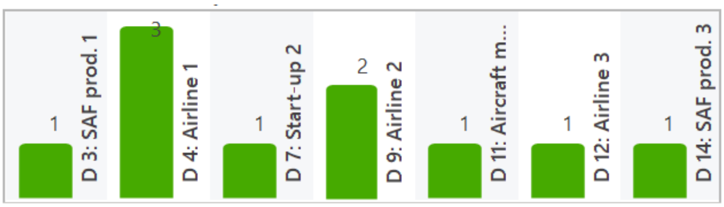

Figure 13: Frequency distribution of mentioning business responsibility

Business responsibility is a motivation from the internal business perspective that some of them feel that they are responsible for the emissions and that it motivates them to do something about it. Aircraft manufacturer 1 states: "*We contribute to global warming with our products and we take our responsibility, therefore, we just make sure that we find ways to minimize our contribution to global warming"* Also, all three airlines feel the responsibility for the carbon emissions whereby airline 3 claims that "*We do have a CEO who is very passionate and authentically believes that we have to do the right thing"* and for airline 1 it motivates them in not being part of the problem but to be a part of the solution. The feeling of responsibility is thus also an incentive to focus on SAF technologies.

The emergence of the market

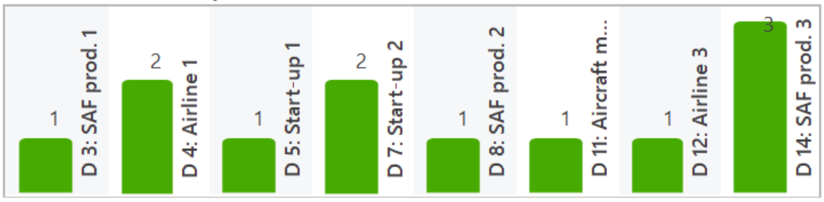

Figure 14: Frequency distribution of mentioning the emergence of the market

Aircraft manufacturer 1: "*We are in a growing market and that also offers us opportunities"*. The market for sustainable fuels is emerging which is for many companies a motivation to step into the market. Airline 1 confirms that the market for SAF is developing and therefore it creates an incentive to start the transition for them. Likewise, both start-ups 1 and 2 see this growth in the market, as a result of which they see an increase of attention for their business but also a lot of new entrants in the market. Start-up 2: "*That there will be a SAF market. There is really no doubt about that and that gives a lot of companies the comfort to step in and the interest to be involved at all. You just see that that market is going to be created, the interest is really high"* This increase in attention is also a positive influence for investors according to airline 3 and SAF producer 3 because the growing market assures investors to put money into the market. With more investments, the development of SAF and the market will increase leading to incentivizing more actors to enter the market.

Employees

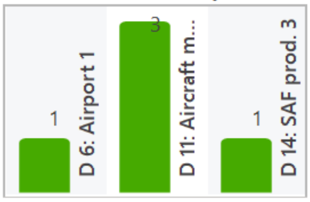

Figure 15: Frequency distribution of mentioning employees

The last positive motivation that is appointed as a factor in the business views is employees and the recruitment. Airport 1 and aircraft manufacturer 1 state that they see increasing pressure from within companies that the employees feel that they have to do something towards sustainability and expect their company to do so. The employees can motivate the company to act more on sustainability, although a side note is that these are generally the younger generation people who feel more sustainable awareness although other employees slowly follow[11]. "*I deliberately say "No, I'm not flying to Toulouse to meet the minister to have a chat for 10 minutes" Then the colleagues all look at me strangely. However, I also notice when I say something like that, they listen and also think about whether it is really necessary to fly all the way there. With that, I try to take a bit of an exemplary function".*

According to aircraft manufacturer 1 and SAF producer 3, also an interesting motivation for sustainable transition is the recent recruitment of new employees. Aircraft manufacturer 1 states: "*The new generation would like to contribute to sustainability and no longer want to work for a polluting company*". Therefore, as a company to be able to recruit younger generation employees, this could become an important motivator for sustainable transition.

5.1.2. Negative motivation

Business profits

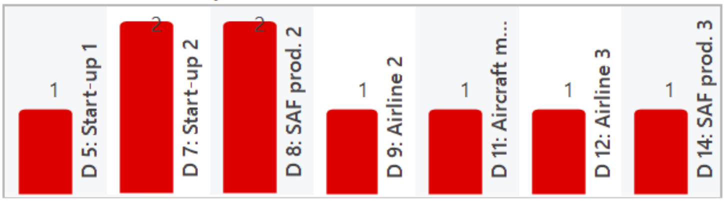

Figure 16: Frequency distribution of mentioning business profits

The aviation industry is a commercial business wherein companies want to make profits but the problem with SAF is that making profits is a hard thing to do. Therefore, there will be companies only focussing on their financial picture such as low-cost carriers as a result of which there will be a lack of motivation towards more expensive sustainable fuels. Something else related to business profits is the commercial nature of the oil industry which has enough demand for biodiesel from the transportation industry. Therefore claims airline 2: *"There is no great incentive at all to start producing SAF for aircraft".* Also, airline 3 states a negative incentive in the business case of biofuel or synthetic fuels as important: "I*t also makes it tricky because you're then having to invest into something that at some point in time becomes obsolete because there are cleaner versions to use"*

Financial space

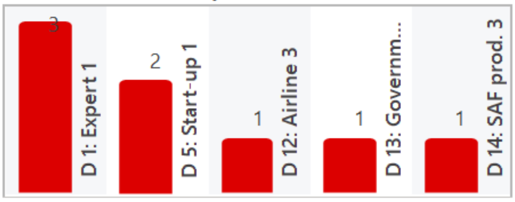

Figure 17: Frequency distribution of mentioning financial space

"*You also got to manage a business and if doing the right thing put you out of business then that's not the smartest thing to do from the financial perspective*". This is a statement made by Airline 3 which is mentioned by multiple actors in the industry for transitioning to SAF options. The lack of financial space is an important negative motivation from the business views. It is strongly related to the previous one, but that one focuses on the lack of profits on SAF, this negative motivator aims at the financial inability. Expert 1 states: "For airlines, there is often very little margin for innovation and that means that they simply don't have the space to buy more expensive sustainable fuels" He phrases it as some sort of squeeze for airlines with very thin margins to adopt SAF by themselves. Start-up 1 confirms this with a lack of budget within airlines and according to him at the beginning, this investment money for the purchase of SAF only came from the marketing budget. It also has to do with some ambivalence of passengers, because they want to compensate SAF but in the end, they will choose the cheapest tickets leaving no financial space for airlines to buy SAF[1,14].

Proof points

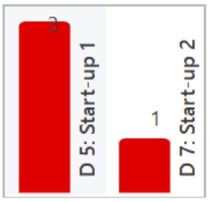

Figure 18: Frequency distribution of mentioning proof points

Both start-ups notice that the lack of large-scale commercial 'proof points' does hinder the adoption of SAF technologies in the industry. Start-up 1 phrases 'proof points' as flagship projects that could incentivize the industry and give confirmation and assurance of the technology readiness. From a business sales perspective are proof points critical components that provide proof that a technology works as claimed. Regarding SAF, large commercial production plants as proof points are needed to motivate the industry to participate, but projects like these keep getting postponed causing a diminishing trust and incentive from the industry.

Certification

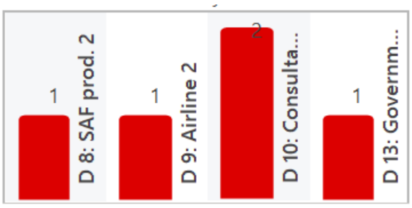

Figure 19: Frequency distribution of mentioning certification

Certification is the last aspect considered important from the business perspective regarding SAF technologies. Airline 2 indicates that they are not in the position to experiment with sustainable fuels or other blending methods, they want the certification from regulators or aircraft manufacturers that SAF is possible and that they are able to use it safely. A lack of this certification will in de end hinder their incentive to expand their SAF adoption.

Another aspect is how companies are not allowed to report SAF as a reduction in their greenhouse gas emissions according to the GHG protocol. Consultant 1 claims that companies can not include the purchase and use of biokerosene on their flights as a reduction in their scope 1, 2, or 3 emissions which decreases the incentive from a business perspective to conclude large-scale contracts for SAF. The consultant claims this as an important demotivator because companies want the validation and quality mark of being sustainable confirmed by an external party. Investing in SAF costs a lot of money but when you as a company won't get the credits and confirmation in return, this can be a serious demotivator.

5.2. Commitment

The second part of the result section gives an overview of the commitments made by the stakeholders toward the development and adoption of sustainable aviation fuels. From the interviews, a large number of statements in a range of different aspects have been collected related to SAF. Similar to the motivation section, a saturation appeared as a result of which the statements have been categorized based on matching conditions that structure all statements as can be seen in figure 20. These categories will be further elaborated on in the following section.

Figure 20: Commitment categories with corresponding statement frequencies

Development of SAF

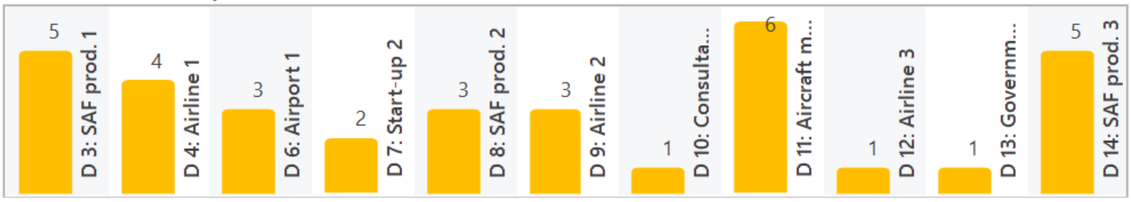

Figure 21: Frequency distribution of mentioning development of SAF

Commitments toward the development of sustainable aviation fuel technologies are claimed by almost all the stakeholders that have been interviewed. It becomes clear that the SAF technologies and the alternative sustainable technologies are still in the early stages of development and none of them is sufficiently developed on a large commercial scale. Therefore, the stakeholders indicate that the commitments toward developments are spread across multiple technologies ranging from biofuels to electric aircraft[3,4,8,10,11,13,14]. This is because it is hard to determine what will be the best for the future which makes it risky to already focus on one specific technology. Apart from the risk, Airline 1 and Consultant 1 argue that by contributing in little bits to every technology, they want to inspire the industry and give future perspective by creating a wide range of technological options for aviation. SAF producer 3 states "*We are investing in a lot of next pathways, we have now HEFA but it is just the starting point of what will be the foundation of the SAF markets*" Related to that, SAF producer 1 argues that they participate in a large number of projects to determine the technology readiness level and contribute to getting technology to a higher level. For example: "In a project, it is often necessary to look at the jet fuel quality, so if it meets the requirements that the ACDM Airport Collaborative Decision Making has set for the quality of JET fuel"

Although the project focus is spread, some stakeholders have indicated some specifics in their commitment to the development: Start-up 2 indicates that they focus on the development of two sorts of synthetic fuel techniques wherein she can't say whether ethanol-to-Jet or Fischer Tropsch will be the most successful. Airline 1 and government 1 also confirmed this with commitments to the development of synthetic fuels although the technology is not yet matured. Airport 1 claims that they are committed to the development of electric aircraft for short distances and aircraft manufacturer 1 focuses besides synthetic fuels also on hydrogen: "*We want to fly the first hydrogen aircraft in 2035 so in about 15 years*"

The last aspect to mention is the competitive commercial nature of the industry regarding the commitments among the stakeholders. Both Airlines 2 and 3 didn't want to comment on the question of whether they are committed to certain projects on the development of SAF. The fact that this information shouldn't be in the public domain restricts them to elaborate on their projects. "*We* *haven't invested yet, but we are working on it. We are in talks with various parties about where we want to invest, but I can't tell you in which ones"*

Upscaling SAF

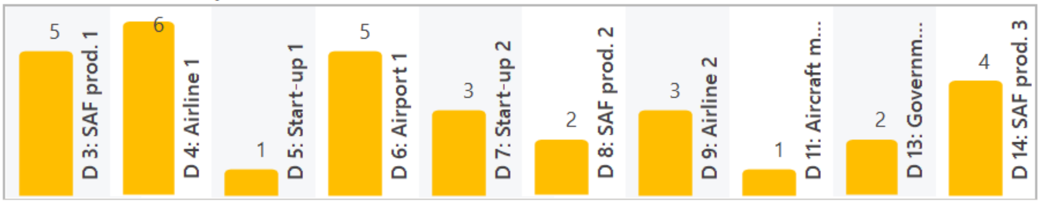

Figure 22: Frequency distribution of mentioning upscaling SAF

From the interviews, it became clear that the production capacity of SAF is an important aspect and therefore several stakeholders have mentioned a commitment to the upscaling of production capacity. Currently, SAF producer 1 is building one of the first production plants solely for biofuels which is almost finished. Likewise, SAF producer 2 recently started with the construction of a biofuel factory. SAF producer 3 is currently the world's market leader in SAF production and with the current undergoing expansions of two facilities, they expect to be able to produce 1,5 million tons of sustainable aviation fuels next year. Commitments for upscaling are thus made, but he also states "*In 2019, the world has been consuming around 330 million tonnes of fossil fuel, so it's still just a drop in the ocean*"

On top of having these production plants in place, the supply of inputs and widening the options are also important for the upscaling. Therefore, the SAF producers and the government are also exploring the possibilities for new feedstock potentials to use for biofuels[3,8,13,14]. The potential and availability of used cooking oils, agricultural residues, and municipal waste can be scaled up whereby the government contributes to this by making supportive policies.

Apart from the biofuel programs, a lot of commitments are also made toward upscaling synthetic fuel programs. Both start-ups are set up with the focus on upscaling the production capacity of synthetic fuel through direct air capture technologies. Enlarging synthetic fuels also receives attention from airlines 1&2 as well as ongoing projects within the SAF producers. Airline 2 states that upscaling has to be done as soon as possible because, with the current low availability, the prices remain very high. However, SAF producer 3 notes that "*We are working on that but having scalable volumes for e-fuels will take another 7-8 years maybe"*

Lastly, airport 1 points to the fact that to scale up the production of SAF, a lot of extra green energy is needed. Therefore, they are focussing on the generation of renewable energy to produce green hydrogen that can be used for the production of synthetic aviation fuels: "*We have a large solar park of 22 megawatts and in cooperation with several companies, we will place an electrolyzer to produce hydrogen and eventually SAF"* She sees airports with an extra purpose in the future because in all the areas around airports it is restricted to build due to safety but it can offer space for upscaling the generation of renewable energy through solar parks.

Development regulation

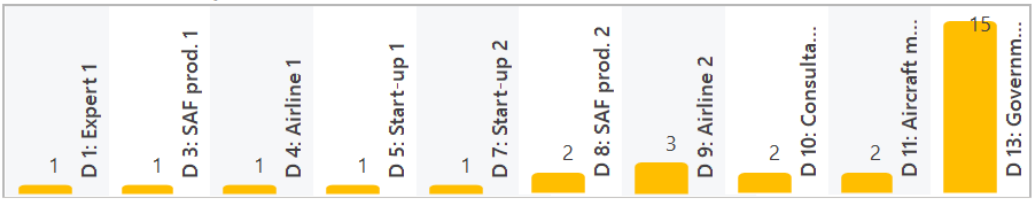

Figure 23: Frequency distribution of mentioning development regulation

"*We are involved in many initiatives where we are talking especially towards policymakers because we believe that more regulation should be introduced to make more sustainable fuels possible"* This is stated by aircraft manufacturer 1, but is shared by many of the stakeholders who are trying to involve governments and aviation authorities in their views and convince them what the possibilities are. Measures such as mandates, certifications, and accountancy standards all contribute to an increase in SAF and therefore many of the stakeholders are committed to projects involving the government[4,5,9,10,11].

In the interview with the Dutch government, many of the commitments to regulatory developments are paid attention to. It is stated that they have evaluated many different options as policy measures that can contribute to the increase in purchase and production of SAF. First of all, they have set their own goal of blending 14% sustainable aviation fuel in 2030 as one of the most progressive countries in Europe. To reach this goal, they have initiated research by an external party on how to reach that goal. Multiple policy measures were evaluated but the conclusion was to set up a blending mandate for the most favorable result. As a result of that, they also committed to the European mandates in the context of the 'Fit for 55' program. However, a mandate of 14% on a European level is due to the lack of feedstock not realistic, but they are committed to shaping the mandate as much as possible[13]. Additionally, due to the price difference between biofuels and synthetic fuels, he is also convinced that an extra sub-mandate is needed for the latter but this is not yet included in Dutch mandates. Lastly, they are also evaluating the possibility of a CO_2 limit over a company's emission which means that if they want to expand, they have to earn it by increasing their sustainability. However, this policy is still being evaluated.

As a disadvantage toward these policy developments, it is stated that a national blending mandate could lead to aviation businesses shifting abroad. Therefore, most of the focus lies on shaping the European mandate[13]. Another note is that it is remarkable that the aviation industry is not included in the Paris agreement and the fit for 55 goals. In the specific goal of a 55% reduction in 2030, aviation is excluded due to its international character. They are expected to contribute with 5% blending, but it lacks a specific emission goal. So this is an interesting critical point of attention where improvements can still be made[13].

Development market

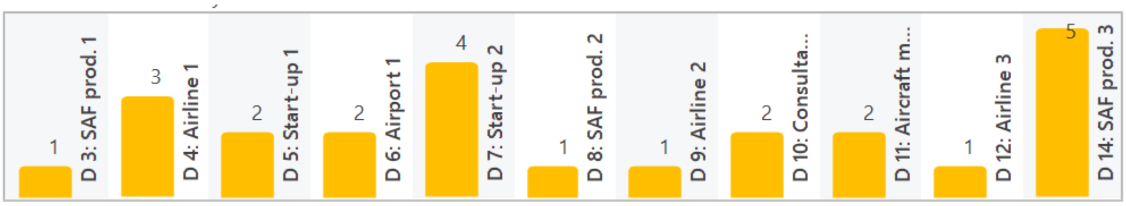

Figure 24: Frequency distribution of mentioning development market

Something that also became clear from the interviews is the commitment to creating and developing a market. Every stakeholder has stated that the momentum is growing and that they have some part in the fast-changing nature of the SAF market. By supplying an increasing amount of SAF, related to upscaling, and offering SAF to not only airlines but also to other corporations, the market will develop in a positive way[3,8,14]. Also, aircraft manufacturer 1 proved that flying on SAF is safe by demonstrating their tests on 100% biofuel. This can give assurance for a future market which then will contribute to an increasing market. Furthermore, all three airlines are participating in constructions in which they can promote the demand, for example by offering the ability for consumers to buy SAF to compensate for their flight. However, it is also indicated that consumers do not always know what their sustainable possibilities are and therefore it also requires an effort to educate passengers on their options[14]. That's why SAF producer 3 notes: "*It can only work if we are working together as an industry. So it's not only the producers, you need certainly the corporates and the airlines but you for sure need regulators to create and develop a functioning market*"

Science-based targets

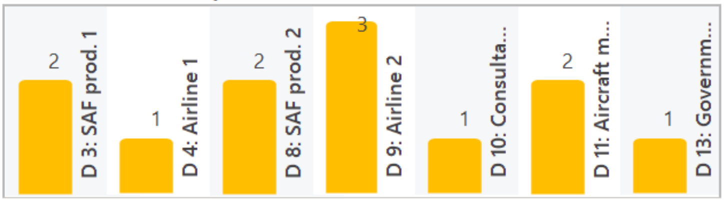

Figure 25: Frequency distribution of mentioning science-based targets

Science-based target is a concept that was often mentioned in the business perspective. An increasing amount of businesses have set up and are getting committed to internal emission targets. These targets are science-based and attached to the goals that have been set by governmental regulations as explained before. Airlines 1 & 2 state that they are both committed to a couple of hard targets including an emission reduction of 30% in 2030: "*You can see that a lot of Airlines have made great strides this year and that quite a few Airlines now have a kind of roadmap ready to which they want to grow*" In line with that, Aircraft manufacturer 1 have set the target to supply all their test flights, transport flights and the delivering of new aircraft with sustainable fuels. She also sees an increase in large corporations, flying frequently for business, setting targets to minimize their flight emissions because they see their relative high impact on the climate[11]. On a critical note, however, setting targets and getting publicity with your ambitions is great, but targets are there to be accomplished and commitments need to be made. Only ambition in the media won't contribute to emission reduction[10].

Offtakes

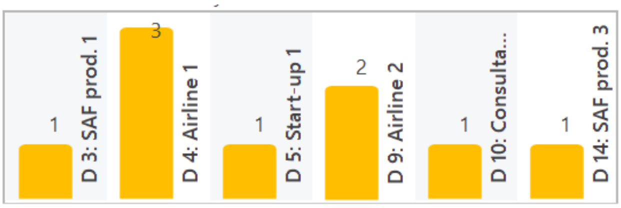

Figure 26: Frequency distribution of mentioning offtakes

As a result of the science-based targets, more and more airlines and corporations are committed to making purchase obligations with SAF producers[3,14]. Consultant 1 made a statement that they have committed to flying on 100% SAF since the beginning of this year. They will fully compensate for their business travels by making SAF offtakes. Likewise, both airlines 1 & 2 made an offtake commitment by which they will fly 0,5% and 1% respectively on all outgoing flights from Amsterdam. SAF producer 3: "*There are certainly more and more corporates that are now thinking about how to compensate for their travel emissions more directly through making obligatory offtakes on SAF*"

5.3. Belief

The third results part covers the beliefs among the stakeholders regarding the sustainable options for the future of the aviation industry. This part can be related to the technical comparison of chapter 3 whether the stakeholder's beliefs are in line with the literature. Therefore, the sub-chapters will elaborate on the four technological options further in detail. Similar to the previous parts, a saturation emerged among the statements regarding the stakeholder's beliefs. The interviews provided insights that biofuels are for the short term, synthetic fuels for the medium term, and electric and hydrogen for the far longer term.

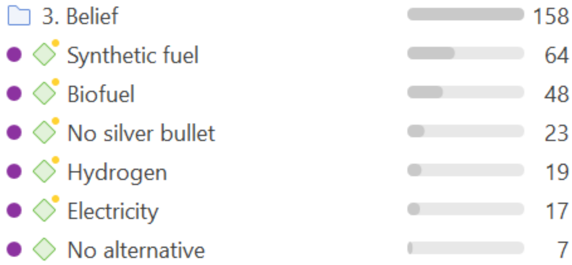

Figure 27: Belief categories with corresponding statement frequencies

No alternative

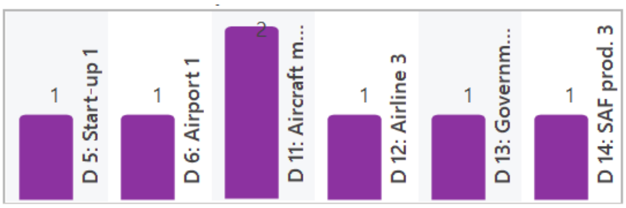

Figure 28: Frequency distribution of mentioning no alternative

First of all: "*Oil is something that will run out and the dependence on oil and gas is not a good thing so we have to look for an alternative"* [14]. The belief among several stakeholders is shared that there is simply no other alternative than SAF in the short term for aviation. The belief is that SAF is the fastest possible way and thus there is a critical role for sustainable aviation fuels to decarbonize the industry and with approaching sustainability goals, there is no way out anymore[6,11,12].

Biofuel

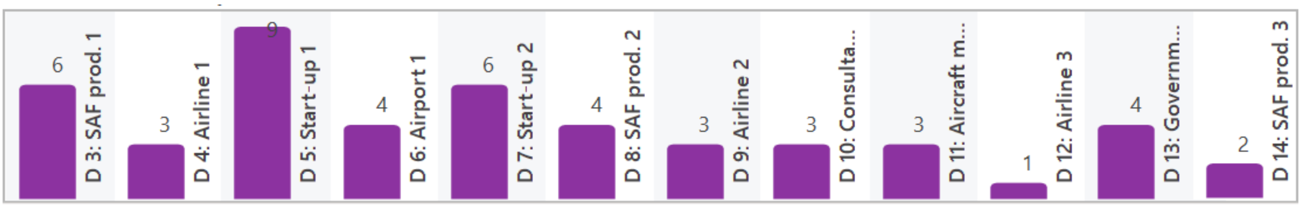

Figure 29: Frequency distribution of mentioning biofuel

SAF producer 3 states: *"The sustainable aviation fuel that we are selling is what we call drop-in solutions. So it can be used as a normal standard fuel and it reduces emissions by 80%. Not the emissions, but the life cycle values reduce by 80% and it also reduces the so-called non-* CO_2 *effects with immediate effect. So there are so many benefits"* These benefits are shared by many of the stakeholders whereby the non- CO_2 effects are fewer SO_x and less particulate matter emissions. Additionally, the technology for biofuels has its advantage that it is currently the most developed and therefore the easiest process making it the relatively cheapest for production[3,4,7,8]. The HEFA technology is also the only technology that has been proven on a commercial scale[5,7,11]. Regarding the use of feedstocks, waste oils and cooking oils are the easiest (ease of technology), but start-up 1 also believes that there is a large potential to explore other sources such as agricultural residues and intercropping. The availability of the feedstock is also a point of attention, but government 1 argues that their research concluded a sufficient amount of feedstock for Dutch aviation should be available in the short term until 2030. "*For 2030, we had calculated that around 537,000 tons of sustainable fuels should be available*"

Nevertheless, multiple stakeholders do believe that the biggest downside is the limitation to the feedstock that will be scarce and will be running out in the long term. Competition between industries on land will also increase which will make it even harder for the industry to have feedstock beyond 2030. Regarding the feedstock itself, processing municipal waste is still a complex expensive technology and it is also important to make sure that the feedstock is really sustainable because mistakes are made in the past relating to the use of palm oil causing deforestation in Asia[5,7]. Still, stakeholders believe that biofuels are our only achievable option now in the short term for aviation. It is definitely seen as only a transition fuel, but most of them believe that until 2030 most of the SAF will be still bio-based fuel.

Synthetic fuel

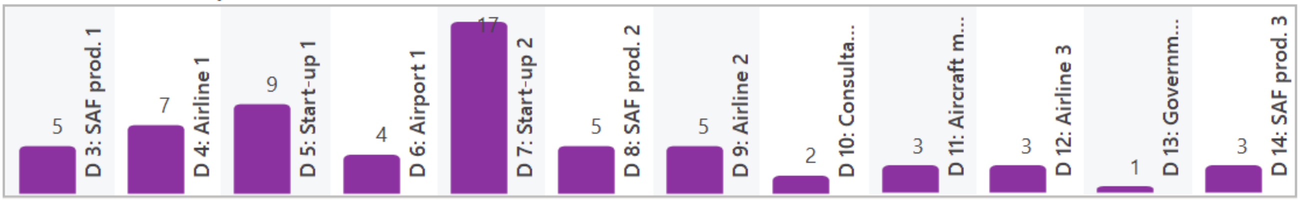

Figure 30: Frequency distribution of mentioning synthetic fuel

Synthetic fuels are sustainable aviation fuels that are believed by many stakeholders that this fuel has the most potential for the mid-long term future of aviation[4,5,6,7,8,9,14]. One of the main benefits is that this is also a drop-in fuel which makes it compatible with all the current engine technologies with a few minor adjustments. To create this fuel, electricity is used to combine carbon and hydrogen into so-called 'syngas', and with two current available power-to-liquid (PtL) processes which are alcohol-to-jet and Fischer-Tropsch synthesis, it can be converted into a liquid aviation fuel[5,8]. The carbon that is used for this fuel is either captured from a point source such as a steel factory or with direct air capture (DAC) technologies. Stakeholders believe mostly in DAC technology because this creates the main benefit of an endless carbon source to produce the fuel and point-source will keep you tightened to a polluting industry[4,7]. Although this fuel still uses a carbon source, the fact that it is captured does result in a net-zero emission on the whole cycle. Therefore, aircraft manufacturer 1 and airport 1 believe and expect that all narrowbody aircraft will be flying on synthetic fuels by 2035.

On the other hand, some stakeholders believe that synthetic fuel also has to encounter some major challenges. The technology is enormously costly to develop and thus needs large amounts of investment, billions according to airport 1. The investments are needed for the development and purchase of expensive electrolyzers producing hydrogen as well as the urgency for large amounts of green renewable energy. To encounter this, ideas are already suggested to engineer production plants in geothermal areas where renewable energy is relatively cheap such as the middle east. But at this moment it still lacks commercial proven production plants which then consequences in a lack of scalable volumes which will not lower the price for the market in the short term[5,7].

Nevertheless, almost all stakeholders have mentioned their belief that net-zero synthetic fuels will be crucial for the aviation industry although the production and scalability are still in development. Especially for long-haul flights will synthetic fuel be important because nobody foresees an alternative for large aircraft on this flight range in the coming 30 years[7].

Hydrogen

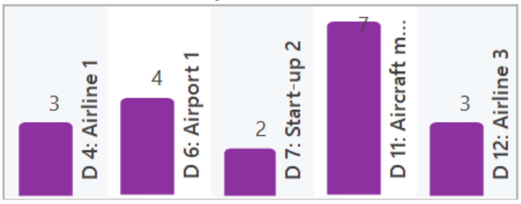

Figure 31: Frequency distribution of mentioning hydrogen

Believed as an alternative sustainable aviation technology compared to fuels is the use of hydrogen which has emission-wise the most potential[4,6,11,12]. The roadmap for this, according to aircraft manufacturer 1, is first the direct combustion of hydrogen into engines that require new engine technology, and second is the use of hydrogen fuel cells to power aircraft with electricity. These technologies still require a large number of developments for commercial aviation and therefore the first small commercial aircraft is not expected until 2035 and a larger one until 2050: "*We expect to see aircraft entering service in the mid-2030s, not the largest Aircraft. Not widebodies, but turboprops and narrow bodies would be expected to start seeing them from 2035*" Even though these aircraft technologies will arrive, stakeholders, believe that they will only be functional to fly on small and medium ranges due to the too low energy density for intercontinental flights.

Electricity

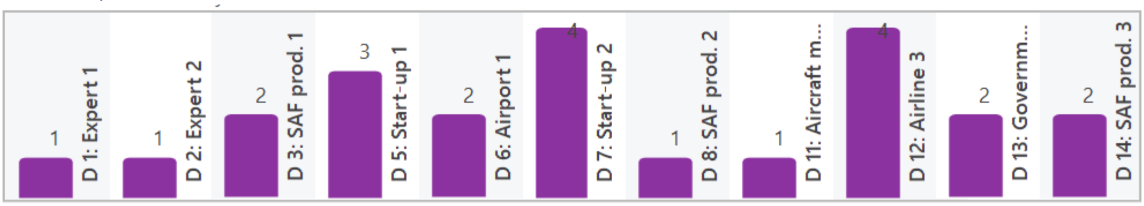

Figure 32: Frequency distribution of mentioning electricity

Similar to hydrogen-powered aircraft, electric-powered aircraft are also believed to be only functional on short distances for small aircraft due to the potential battery technology range[3]. Airline 1 states: "*I believe that electric flying will be done but on a very small scale. I predict that the first electric scheduled flights will open in 2026, such as to Brussels with 9 people. Ultimately, at the end of the decade, that will go more towards maybe 20 people, but the distances remain short in the order magnitude of 300 to 400 km.*" An interesting aspect related to this is the statement by airport 1 who believes that electric flying could become a new form of modality within Europe. By flying point-to-point between European regions it could connect Europe in a different way "*Now you drive from here to Hamburg in 5 hours which is very inconvenient, an electric plane could get you there in 1,5 hours*" Nevertheless, no stakeholder believes that electricity-powered flying could substitute the large commercial aviation for long-haul flights in the future.

No silver bullet

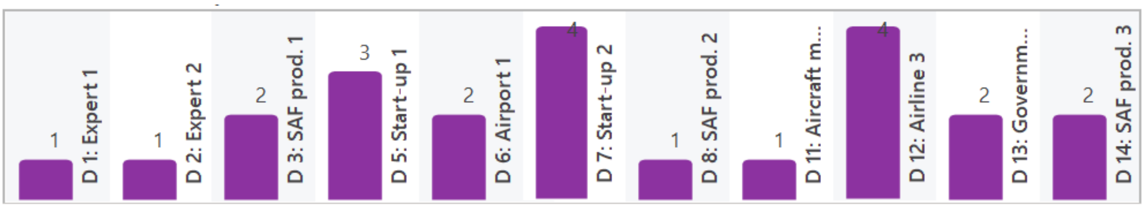

Figure 33: Frequency distribution of mentioning no silver bullet

"*There is no Silver bullet, it takes some sort of combination of everything to do this*" This statement by SAF producer 1 is shared in the beliefs of many of the stakeholders that have been interviewed. There is a whole range of sustainable technologies but no single technology is believed to be the sole solution that creates net-zero aviation. It is believed that every bit will help and every technology will start a transition toward lowering the emission. Also, aspects such as more efficient aircraft and simply lowering the frequency of flying will adhere to decreasing carbon emissions of aviation. SAF producer 3 states it sharply: "*With every percent that we add we're doing something and I find that much better than waiting for a silver bullet because if we wait until 2035 we don't have to worry about the climate any longer because we cannot change it anymore*"

5.4. Adoption factors

Following the motivations, commitments, and beliefs, the 10 adoption factors from van der Kaa et al. (2011) are also used as code categories. All categories are mentioned by the stakeholders in their statements and therefore they will be elaborated on in this part. The factors have quite some overlap with the previous results and therefore every adoption factor is related to the parts of the previous sections. Nevertheless, also some new insights have come to light from the stakeholders' business perspectives.

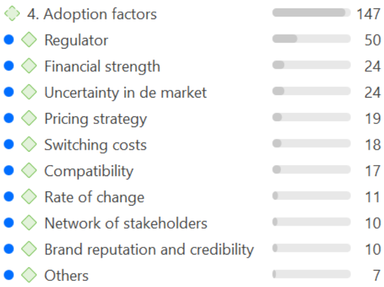

Figure 34: Adoption factors with corresponding statement frequencies

Regulator

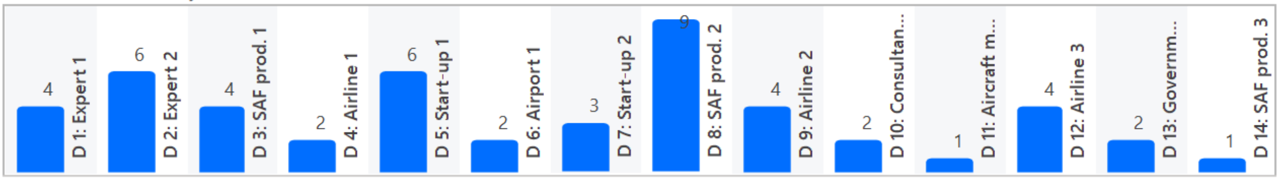

Figure 35: Frequency distribution of mentioning regulator

The first and by far most mentioned adoption factor for the aviation industry is the influence of the regulator. It has already become clear from the motivations that the regulator has a large significance in the adoption of SAF technologies. The policy implementation such as the blending mandate from the Dutch government as well as the European fit for 55 program is presumed a powerful and important driver to accelerating the adoption: "*A mandate will simply bring really significant volumes onto the market. I think that's super nice, which actually makes the demand from companies less important*" [5] Also, regulation developments such as more certifications, better accountancy standards, and financial instruments are important stimulators to give more clarity and direction for the adoption according to the stakeholders. Airline 3 states: "*The earlier that there can be clarity from a policy and specifications level on what is acceptable, then that narrows the options that are there. So it then allows for a more focused effort on the things that are going to work and on the flip side it also then encourages more investment in the areas that do work*"

A counterpart of the increase in regulatory influence is that it could make it less easy and less clear to understand all the regulations according to airline 1. Especially the Dutch government is in a complex situation where they have to cope with multiple regulatory discussions regarding not only carbon emissions but also emissions of nitrogen and particulate matter[6]. Nevertheless, all stakeholders argue that the regulatory bodies have a strong influence in the facilitation and support of SAF adoption.

Financial strength

Financial strength, defined as the financial condition of the company and its future prospects considering investments and helping start-ups is also presumed important among many stakeholders. It is already mentioned that billions are needed for the SAF sector and these investments are only likely to come from major financially strong corporations such as oil and SAF producers or aircraft manufacturers[2,4,6,10]. On a lower level, the ability of airlines to adopt SAF is more limited due to their financial space as mentioned as a negative motivator. Therefore, the strength of business from a financial perspective can thus have a large influence on the acceleration or deceleration of the adoption process.

Uncertainty in the market

The market for SAF is still in the early stages of development with no clear technological pathway and scarce amounts of produced volumes. This does create quite some uncertainty in the market which has also been appointed as negative motivation due to a lack of proofpoints. Airline 3 states: "*I think SAF is critical but because it's seen as a transition pathway, it also makes it tricky because you're then having to invest into something that at some point in time becomes obsolete because there are cleaner versions to use"* Therefore, this is also considered a factor that currently decelerates the adoption. Nevertheless, lots of commitments are made toward upscaling and the development of the market as well as the fact that market emergence and future business create positive motivations for adoption.

Compatibility

Following the uncertainty in the market, the compatibility of the technology also has an important adoption role. Many commitments toward SAF development are made whereby both biofuels and synthetic fuels are drop-in fuels and thus compatible with the current engine technology compared to hydrogen or electric technologies. Therefore, many of the stakeholders believe that in the short and medium-term a large role is reserved for SAF. Also, regulators and aircraft manufacturers support the use of SAF through testing aircraft and working on certification. Aircraft manufacturer 1: "*Technically is SAF compatible because in principle they are the same type of molecules that emit even less harmful substances during combustion"* The fact that SAF is compatible is thus also a strong driver for business adoption.

Switching costs

Something that has already come to light multiple times is the fact that the transition toward SAF and other sustainable technologies costs large amounts of money. Biofuels are the relatively cheapest way for aviation to lower emissions, but even this is multiple times more expensive than current conventional kerosene[9]. This is caused due to development costs and the low availability versus the rising demand from the market as a result of which the price for SAF stays very high. The current high costs to switch do play a crucial role in adoption which is also argued by Expert 1: "*The cost estimate will determine whether or not it will be introduced. If you now opt for 100% sustainable, you will drive yourself bankrupt*" Therefore from a financial business perspective, the switching costs for SAF and other technologies are confirmed as an influential factor for the adoption.

Pricing strategy

To counter the high prices of SAF technologies, pricing strategies can be very important in contributing to adoption. As the negative motivation 'Financial space' has indicated, airlines have a small margin for innovation and the purchase of sustainable fuels. Therefore, many of the stakeholders have argued that with pricing strategies this can be partly overcome. Putting more responsibility on the consumer by increasing the ticket price could create more investment money, but the danger lies in the low-cost carriers who will create unfair competition. Also, constructions for the voluntary side have been set up to additionally pay for SAF over your own ticket. These kinds of strategies on the price of flying are therefore also important for adoption according to the stakeholders.

Rate of change

The rate of change is an adoption factor that is positively affected by the motivations of sustainable awareness and future businesses. As mentioned in the awareness, start-up 1 argues that we have to act now, rather sooner than later. However, the aviation industry is a relatively slow-changing industry towards sustainability according to multiple stakeholders[2,4,10]. Airline 1 states: "*We still see far too many mechanisms that maintain the fossil fuel industry. We have economic patterns that perpetuate a lot of things that should really change, so that transformation needs to be driven*" Changing regulations such as mandates as well as corporations setting science-based targets and doing offtakes display progress in the rate change, but still things need to happen for the acceleration of SAF adoption.

Brand reputation and credibility

The adoption factor of brand reputation and credibility is logically strongly related to the positive motivation of reputation mentioned in the first part of the result section. That part has largely elaborated that the sustainable reputation of companies plays an important role in deciding to adopt SAF. Companies that want to profile themself as someone who delivers a contribution to the environment by decreasing their carbon emissions. Therefore this adoption factor is also important to incorporate for adoption according to many of the stakeholders.

Network of stakeholders

The last adoption factor from the literature is the network of stakeholders that are presumed crucial for SAF. This is shared among multiple stakeholders and that is also already mentioned by SAF producer 3 in the 'Development market' part. The aviation industry and the related SAF sector is a complex intertwined system of multiple stakeholders that all influence the success of sustainable aviation. SAF producers, Airlines, Aircraft manufacturers, consumers, and especially regulators are all needed to work together in this system to support SAF and create a net-zero emission industry.

Others

The last aspect that came to light and is worth mentioning is an environmental factor that influences the rate of adoption. Large radical changes can have a big sudden impact on in this case adoption. Two stakeholders have pointed out that due to the current situation in Ukraine with Russia, the EU has decided to get rid of the dependence on Russian fossil fuels. With this in mind, many people realized that they maybe could decrease their energy consumption or focus more on sustainable alternatives. This perspective change can suddenly accelerate the energy transition and therewith the adoption of technology such as sustainable aviation fuels.

5.5. Differences over the years

Followed on the adoption factors, the stakeholders are also asked what the main differences are in the aviation industry towards sustainable aviation fuels compared to 5 to 10 years ago. The aspects that are often mentioned are the lack of pressure, sustainability being less of a 'hot item', and the low financial return for SAF about 10 years ago[7,12]. In the past years, sustainability was much more of a marketing aspect or a 'show case' paid from marketing budgets to show that you as a company participate in the sustainability issue[3,5]. Back then, only the purchase of CO_2 certificates was often enough to do your sustainable part.

More to the technical part, about 10 years ago it lacked lots of certifications and in general, only test flights on SAF were being done[5,11]. Besides, the ability to purchase SAF was also not yet possible due to lacking commercial production of the fuel[7]. Regarding regulation, there was not yet a specific program for SAF and the government gave no regulatory direction to stimulate the industry. Most of the technical focus back then was on aircraft and fuel efficiency, but not yet on new types of fuel[6].

Looking at what has changed until now is the enormous growth in sustainable awareness. People and businesses have increased attention toward sustainability and are pushing more for decreasing the emissions. In the last couple of years, more coalitions, alliances, and working groups have been established that contribute to the development of sustainable aviation[3]. Many of the stakeholders see momentum being built and think that we are heading toward a tipping point in sustainable awareness. As a result of that, SAF is becoming more widely known in society which increases the fast-changing market and increases the market participants causing positive concurrency[5,7,10,12]. Aircraft manufacturer 1 saw the last couple of years a slow change from carrying out single flights with SAF to a series of flights in the flight schedule.

The change compared to 10 years ago is also seen in the emission targets that are being set by an increased amount of corporations. Awareness is growing and therefore companies are setting goals to reach in the future. The government and EU also play a large part in this by an increase of policy interventions and steering toward sustainable solutions. More certifications and easier procedures are also changed compared to years ago which now contribute to SAF development. The aviation industry has thus undergone some positive change over the last years, but to remain in business with the expected growth of aviation, still, lots of things have to improve in terms of sustainability.

5.6. Results overview

To finalize the result section, this part gives an overview of the core results regarding the motivations, commitments and beliefs. Tables 9, 10 & 11 presents all the factors with a core explanation.

Motivations

Table 9: Positive & negative motivations

Positive	
Sustainable awareness	It is one of the most mentioned motivation because the business environment is changing especially among corporates realizing that the carbon emitted by the aviation industry has a large climate impact that needs to be reduced.
Regulation	This is the other most mentioned motivation because the requirement from the regulators with blending mandates put pressure and will create an increased motivation from businesses to lay more focus on the use of SAF.
Society & Consumer	The emergence of societal pressure and the public perception of sustainability is causing a serious push in motivating businesses to decrease their emissions
Reputation	As a corporate business, it is getting more and more important to profile yourself as someone who delivers a contribution to the environment by decreasing your carbon emissions
Future business	Companies recognize that innovating and investing in new sustainable technologies such as SAF is crucial for the future of their business. This increases the rate of change in the industry.
Pioneering	Some companies have the drive of being the front runner and wanting to be an early adaptor for the industry
Business responsibility	All three airlines feel the responsibility for their carbon emissions that motivates them to do something about it.
Emergence of market	The market for SAF is growing which offers opportunities and create an incentive to step into the market
Employees	The new generation would like to contribute to more sustainability motivating businesses toward sustainability through employees.
Negative	
Business profits	The aviation industry is a commercial business wherein companies want to make profits but making profits with SAF is challenging. High switching costs demotivates the adoption.
Financial space	There is often very little margin for innovation which means that airlines don't have the space to buy expensive SAF relating to the financial strength.
Proof points	The industry lacks ‘flagship projects’ that could incentivize the industry and give confirmation and assurance of the technology readiness. This uncertainty in the market demotivates companies.
Certification	The lack of certification on SAF technology and safety as well as reporting in GHG protocol demotivates industries to expand SAF adoption

Commitments

Table 10: Commitments

Development SAF	Commitments toward developments are spread across multiple technologies ranging from biofuels to electric aircraft. Contributing in little bits to every technology inspires the industry and gives future perspective by creating a wide range of compatible technological options for aviation
Upscaling SAF	Building biofuel production plants, exploring feedstock potentials, upscaling synthetic fuel capacity, and upscaling renewable energy generation are being done that can all adhere to decreasing the uncertainty in the market.
Development regulation	Development Dutch 14% blending mandate and shape EU mandate. Evaluating possibility of CO_2 emission limit. Remarkable that aviation is excluded from emission goals, only has a 5% blending mandate.
Development market	The momentum is growing and all stakeholders have some part in the fast-changing nature of the SAF market. Airlines have constructions in which they promote the demand such as SAF purchase compensation through pricing strategies.
Science-based targets	An increasing amount of businesses are getting committed to science-based emission targets such as an emission reduction of 30% in 2030. However, ambition won't contribute to emission reduction yet.
Offtake	Increase in purchase obligations such as flying on 0,5% or 1% on all outgoing flights from Amsterdam

Beliefs

Table 11: Beliefs

No alternative	The belief among several stakeholders is shared that there is simply no other alternative than SAF in the short term for aviation
Biofuels	Drop-in solution, reduces life-cycle emission by 80%, easiest process, relatively cheapest, and proven on a commercial scale. However, belief in limitation feedstock is the biggest downside
Synthetic fuels	Believed as most potential for coming 30 years. Drop-in solution and net-zero emission cycle. All narrowbody aircraft will be flying on synthetic fuels by 2035. Downsides are costs and require a large amount of renewable energy.
Hydrogen	Zero-emission technology, however, requires new engine technology. Believed only be functional on a small range due to low energy density
Electricity	Believed that electric flying only will be on a very small scale. Could become a new form of modality by flying point-to-point between European regions
No silver bullet	There is a whole range of sustainable technologies but no single technology is believed to be the sole solution that creates net-zero aviation. Every bit is needed by every stakeholder in the network.

6. Conclusion & Discussion

6.1. Conclusion

This research tried to answer the main research question: *What are the motivations, commitments, and beliefs of aviation stakeholders with respect to promising sustainable aviation fuel technology?* It was an exploratory study using a qualitative research approach. A conceptual framework was constructed based on innovation and business theories. This framework showed the coherence between the theories and the scientific relevance regarding the importance of these adoption factors for an innovation like SAF to become successful. From these theories, potential adoption factors were collected but the theories lacked specification, degree of importance and a concise list of all relevant adoption factors reflected by the industry. Therefore, to explore and specify these factors, 14 interviews with relevant stakeholders from different aviation backgrounds were conducted. These interviews have brought some valuable insight regarding the specification of motivations, commitments, and beliefs among stakeholders toward promising sustainable aviation technology as presented in table 9, 10 & 11.

The research gave insights into the trend, which is in line with the conceptual framework, that over the last couple of years sustainable awareness in the industry is increasing a lot and therefore it is one of the most important motivations to start adopting SAF. SAF is becoming more widely known and it is believed that momentum for a sustainable transition is being built in the industry. The factors that have been found regarding the emergence of societal pressure, emergence of public perception of the consumers and the increased importance of a sustainable reputation may also already been known, but the degree of importance was not clear. From this research it can be concluded that these factors are causing a serious motivational push for the industry.

Motivational factors that can be concluded as new knowledge from on this aviation case are that businesses feel responsible and see that aviation needs to become more sustainable for the future otherwise they become a bankrupt industry due to rising carbon emission restrictions. Also, a new interesting factor is that younger generation employees don't want to work in a polluting company anymore causing recruitment also to play a role in the motivation for a sustainable transition within companies. Nevertheless, the research can conclude that although they belief in SAF and are motivated by sustainable awareness, the implementation of regulations is strongly demanded to create motivation for adoption in the industry. The industry explicitly claims that they require the implementation of blending mandates that cause pressure which is needed to motivate businesses to already start adopting SAF. It shows that internal motivation like awareness is not sufficient and thus the industry demand an external motivation like regulation to give the technology a boost. The growth of this regulatory direction with blending mandates is therefore a large difference compared to 10 years ago.

Furthermore, one of the adoption factors regarding commitments in the conceptual framework was entrepreneurial activities which is in line with the insights given by the research that over the years an increase in a lot of technological development is being done spread across multiple technologies. The main commitments and beliefs lies on SAF technology but also electric-powered and hydrogen-powered aircraft are already in development. A regulatory blending mandate is crucial and therefore the government is increasingly committed the last couple of years to shaping this on a European level in the 'fit for 55' program. Also interesting is the commitment towards regulation development by the evaluation of a potential CO_2 emission limit for corporations causing that the ability to grow requires more sustainable contribution. The last aspect to conclude that reflects relevant new commitments for a transition over the last years is the large increase of science-based targets being set by companies and obligatory offtakes of SAF that adheres to the SAF adoption. However, emission targets are easy to set but now it is crucial that the commitments to achieve them need to be made.

The industry is still in the early stages of the sustainable, but this research has explored and specified various motivations wherein regulation is concluded to be the most required despite the growing sustainable awareness. Followed on this, the research concludes that multiple novel commitments are explored that are being made, and the research determined that the beliefs are heading in the same direction which will all adhere to parts of a sustainable transition in the aviation industry.

6.2. Discussion

6.2.1. Scientific contributions of this study

Reflecting on the exploratory literature part of the research regarding the technology comparison, the research validates the aspects that have been found regarding the technologies. The beliefs of the stakeholders confirmed that currently the most developed and commercially available technology are biofuels but limitations of feedstock will be a problem. Most belief is on synthetic fuel technology for the short-medium term due to the net-zero lifecycle of the fuel. However, the main contribution of this research part to the current scientific knowledge is that it became clear from the business perspectives that they believe that there is no silver bullet and thus every part of all sustainable technologies are needed for a net-zero emission industry.

The core of the research investigated the literature gap regarding social feasibility and in specific the adoption factors of stakeholders in promising aviation technology. The literature review and the constructed conceptual framework indicated that a clear view on the specification and the importance of social adoption factors was lacking in previous research. Therefore, the strength of this research is the contribution to the scientific knowledge base by the exploration and specification of multiple adoption factors stated interesting for a future sustainable aviation industry. Motivation, commitment, and belief are more general adoption factors in the literature whereby the strength was that this study has specified what type of factors fall under these general social adoption factors. Aspects such as the growing sustainable awareness and the requirement of regulations were already mentioned by literature, but their large importance is now validated. More newly specified are factor types under motivation such as attracting new generation employment, pressure from society & consumer, the future of their business and pioneering. Also commitments are more specified into the development of technology, regulation and market as well as the upscaling of the technology.

The adoption factor types that have been specified by the industry can be added to the conceptual framework to have a better understanding on the sociological factors that influence a transition of a sustainable technology. Existing literature argued that sustainable transitions are different than historical transitions whereby the now specified adoption factors contribute to enrich the view on these differences in transitions. Also regarding the theoretical functions of an innovation system, this research contribute to specifying the type and relevance of certain adoption factors that can be included in these functions. Lastly, this research contributes to the enrichment of the theory on niche development aspects in a sustainable transition between the niche and the current regime by the specification of adoption factors types underneath motivation, commitment, and beliefs for new sustainable technology.

6.2.2. Policy contributions of this study

Considering the specification of the adoption factors on regulation, one of the strengths of this research is that it can contribute to insights for new policy implementation. It became clear that regarding sustainable innovations like SAF, an obligatory blending mandate is strongly required to get the industry motivated and moving. The government is already evaluating a CO_2 limit for companies but also (the lack of) certification is determined as new negative motivation, which could be a relevant new insight for public authorities to focus on this to give innovations a boost in the society. Although a policy implementation such as a blending mandate or certification is specific for the aviation industry, the importance of regulatory intervention could be incorporated by sustainable innovations in general. The sustainable awareness is growing, but public authorities need to implement regulations to motivate them which may be similar in other fields.

6.2.3. Industry contributions of this study

It may also be possible to take the new types of adoption factors broader than only the aviation industry. Other industries, for example the energy industry who encounter sustainability matters, may also benefit from the knowledge that new generation employees would like to contribute to more sustainability which can influence a companies drive to sustainability. Similarly, other industries could take lessons from the fact that society & consumers increase pressure, the sustainable reputation of a company plays a significant role and the contribution to innovation in sustainability is important for the future existence of businesses.

Actors in other industries could also use the specification of the different types of commitments that have to be made for sustainable innovation. Not only technological development is important, also sustainable technology require a lot of focus on regulation development and market development to become successful. Furthermore, the energy industry could for example use the knowledge of the importance of science-based targets and commitments on obligated volume offtakes to make a start in the sustainable transition.

6.2.4. Limitations

A limitation of this research can be stated that the external validity is questionable. 14 interviews are held for gathering the data which makes it hard to generalize it for the whole aviation industry. Due to the large international character of aviation, collecting a complete generalizable view of all the motivations, commitments, and beliefs in this complex intertwined system is challenging. However, in these interviews emerged a saturation on most of the aspects so this could also argue that the external validity is sufficient. Also, most of the stakeholder groups are interviewed but the groups were not equally distributed. The aim was to equally distribute the interviews from all different stakeholder groups, but by reaching out to stakeholders it became clear that response rates were lower than expected. This causes that the results could be potentially biased toward a specific stakeholder group with more respondents than others. The combination of the low response rate with the time scope of the master thesis caused that a deadline had to be set for data gathering. Also the fact that conducting interviews is time consuming for both parties, the interview data is not extra verified by the interviewees after transcription by sending it back and let them check their statements.

Another limitation is that only people with high sustainable awareness in the company were spoken causing a potentially biased supportive view towards sustainability. The interviewees were often program leaders on sustainability projects within the company. This could cause an enriching image of their sustainable motivations and commitments and thus the image could be sketched. Following that, two airlines referred to the fact that some of their information is confidential and thus could not answer certain questions. This may also lead to an incomplete view of the industry.

6.3. Recommendations based on this research

This study has explored the motivations, commitment, and beliefs of relevant stakeholders in the industry toward sustainable aviation fuel and other sustainable technology. The fact that a scientific knowledge gap is present on the wider social feasibility of SAF technology argues that more research on this subject is recommended than only on technology and economics. The importance of the socio-technical side of SAF in this industry has to be set more on the scientific agenda. The scope of this study was on European stakeholders, although most of the interviewees were from the Netherlands. It is recommended that additional studies must be done including more European countries or lay the scope on other continents. Cultures, as well as the markets, differ in for example the United States and perhaps their business perspectives could lead to other motivations, commitments, and beliefs. The scientific base regarding these adoption factors is still lean and therefore more exploration of potential factors is advised to enlarge the scientific knowledge.

From a regulatory point of view, based on this research it is recommended for policymakers to lay a lot of focus on the development of regulations that stimulate the adoption of SAF. As this research has indicated, regulations such as blending mandates for the industry are of large importance and therefore is shaping this on a European level crucial. They need to investigate and test the most optimal SAF regulations wherein companies start their transition. Since synthetic fuels are believed as the best solution for the future, it is recommended to further investigate the implementation of a supplementary blending mandate specific to synthetic fuels.

For the industry, the results of this research could be a helpful tool for companies or consultants to use to accelerate the adoption of sustainable technology in aviation. The positive motivations can be used at the negotiation table or as advice for firms as a supportive base to start adopting SAF. The negative motivations can be helpful for consultancy firms or corporations to try to tackle these for SAF expansion. It is also recommended to use the aligned beliefs among the stakeholders in the SAF technology to provide assurance for SAF producers and investors to expand the SAF production and the SAF market. This study can adhere as a small part in setting in motion the sustainable transition in aviation.

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8. Appendices

Appendix A: Interview guides

English

Open start

- What is your current function and background?
- What is your relation to sustainable aviation fuels?
- Which SAF technology do you think has the most potential for a sustainable future in aviation?

The core of the interview

- What are the drivers and motivation for you and your company to focus on SAF technologies?
- To what extent are you and your company committed to the development and usage of SAF?
- Do you and your company believe in these promising SAF technologies
- What are the most important factors for the adoption of SAF technology for Aviation from a business perspective?

Extra information

- What are the main differences for SAF compared to 10 years ago, present, and potential future?
- Who are and what do you expect from other stakeholders relevant to this industry?
- What kind of role do they play in this situation?

Dutch

Open start

- Wat is uw functie en achtergrond?
- Wat is uw relatie met duurzame vliegtuigbrandstoffen?
- Welke SAF-technologie heeft volgens u het meeste potentieel voor een duurzame toekomst in de luchtvaart?

De kern van het gesprek

- Wat zijn de drijfveren en motivatie voor u en uw bedrijf om zich te concentreren op SAF-technologieën?
- In hoeverre zetten u en uw bedrijf zich in bij de ontwikkeling en het gebruik van SAF?
- In hoeverre geloven u en uw bedrijf in deze potentiële SAF-technologieën?
- Wat zijn de belangrijkste factoren voor adoptie van SAF in de luchtvaart vanuit het bedrijfsperspectief?

Extra informatie

- Wat zijn de belangrijkste verschillen voor SAF in vergelijking met 10 jaar geleden, het heden en de mogelijke toekomst?
- Wie zijn en wat verwacht je van andere stakeholders die relevant zijn voor deze branche?
- Wat voor rol spelen zij in deze situatie?

Appendix B: Interview transcripts

Raw data can be requested by reaching out to the researcher

Interview 1 Expert 1

Interview 2 Expert 2

Interview 3 SAF producer 1

Interview 4 Airline 1

Interview 5 Start-up 1

Interview 6 Airport 1

Interview 7 Start-up 2

Interview 8 SAF producer 2

Interview 9 Airline 2

Interview 10 Consultant 1

Interview 11 Aircraft manufacturer 1

Interview 12 Airline 3

Interview 13 Government 1

Interview 14 SAF producer 3