



Sustainable Aviation Fuels (SAF) and its Importance: Could it be a Solution for Skopje's Air Quality Improvement and Emission Reduction?

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Abstract

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<p>This thesis investigates the role of Sustainable Aviation Fuels (SAF) in reducing emissions and improving air quality in Skopje, one of the most polluted cities in Europe. The research includes an analysis of SAF types and benefits, as well as the challenges and opportunities for their implementation in aviation.</p> <p>The methodology is based on qualitative research through semi-structured interviews with key stakeholders, including policymakers, aviation industry leaders, environmental experts and community representatives. Findings suggest that SAF can significantly contribute to reducing CO2 emissions and enhancing Skopje's urban living environment.</p> <p>The thesis also provides recommendations for local stakeholders to support the integration of SAF in the aviation sector and highlights the need for further research on long-term sustainability and public awareness.</p>
Keywords Sustainable Aviation Fuels (SAF), Skopje, air quality, emission reduction, regulatory challenges, green aviation

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Introduction

The rapid growth of the aviation industry has brought significant economic benefits globally, but it has also contributed to increasing environmental concerns, particularly regarding greenhouse gas emissions and air quality degradation. Among the array of solutions proposed to address these issues, Sustainable Aviation Fuels (SAF) have emerged as a promising alternative to conventional fossil fuels, offering a potential pathway to achieving lower carbon emissions and enhancing environmental sustainability in the aviation sector.

Skopje, the capital of North Macedonia, is known for its severe air pollution, which poses significant health risks to its residents and challenges the city's sustainable development. The intersection of urban pollution and the aviation industry's environmental impact presents a unique context for examining the potential of SAF in mitigating these issues. This thesis explores the viability of SAF as a strategic approach to improving air quality in Skopje and contributing to the reduction of aviation-related emissions.

The significance of this research lies in its potential to provide an evidence-based assessment of SAF's role in urban environmental management. By focusing on a city that faces critical air quality challenges, the study aims to contribute to the broader discourse on sustainable aviation and its integration into urban settings.

Objectives and Research Questions:

The primary objectives of this thesis are to analyze the potential of SAF to reduce CO₂ emissions from aviation in Skopje, assess the impact of SAF adoption on improving air quality, and identify the key challenges and opportunities associated with its implementation. The study will address the following research questions:

- How can SAF contribute to reducing CO₂ emissions in Skopje's aviation sector?
- What are the potential impacts of SAF adoption on the city's air quality?
- What challenges and opportunities exist for the integration of SAF in Skopje?

Overlay Matrix

Additionally, an overlay matrix (Table 1) was incorporated to illustrate the relationship of the research questions with the interview questions and clarify the relevance of the empirical findings, which are analyzed and presented in the Results and Discussion chapters. The main research questions can be found in the Introduction section, while the interview questions, together with the interviewees' profiles overview, are presented in Appendix 1 and Appendix 2, respectively.

Table 1: Overlay Matrix

Research Question	Theoretical framework	Interview Questions	Results	Discussions
RQ1: How can SAF contribute to reducing CO₂ emissions in Skopje's aviation sector?	2.1 2.2.1 2.3.1	Q1, Q3, Q5, Q10, Q16	Chapter 4: Results	Chapter 5: Discussions
RQ2: What are the potential impacts of SAF adoption on the city's air quality?	2.1 2.2.1 2.3.1	Q2, Q4, Q5, Q10, Q11, Q12	Chapter 4: Results	Chapter 5: Discussions
RQ3: What challenges and opportunities exist for the integration of SAF in Skopje?	2.1 2.1.2 2.2.1 2.2.2 2.3.1	Q7, Q8, Q9, Q13, Q14, Q15	Chapter 4: Results	Chapter 5: Discussions

1 Theoretical Framework

1.1 Overview of Sustainable Aviation Fuels (SAF)

Sustainable Aviation Fuels (SAF) are advanced biofuels specifically designed for use in aircraft engines. They are considered a key element in the aviation industry's efforts to reduce its carbon footprint and achieve long-term sustainability goals. Unlike conventional fossil fuels, SAFs are produced from renewable resources such as agricultural residues, waste oils, and even non-food crops. This transition to more sustainable sources is crucial for the aviation sector, which is responsible for approximately 2-3% of global CO₂ emissions (International Air Transport Association, 2019).

The development of SAF is driven by the need to address the environmental impact of aviation, especially in the context of increasing air traffic and stringent regulatory frameworks aimed at reducing greenhouse gas emissions. One of the key benefits of SAF is its potential to reduce lifecycle carbon emissions by up to 80% compared to traditional jet fuels (de Jong et al., 2017). This significant reduction is achieved through the use of feedstocks that absorb CO₂ during their growth cycle, offsetting the emissions produced during fuel combustion. Additionally, the adoption of SAF can lead to a decrease in other harmful emissions such as sulfur oxides (SO_x) and particulate matter, contributing to overall air quality improvement (ICAO, 2018).

SAFs can be categorized into several types based on their production processes and feedstocks. The most common types include Hydroprocessed Esters and Fatty Acids (HEFA), Fischer-Tropsch (FT) synthesized hydrocarbons, and Alcohol-to-Jet (ATJ) fuels. HEFA fuels are derived from lipids, such as vegetable oils or animal fats, through a process of hydrogenation and refining. This type of SAF is the most commercially viable and widely used due to its similarity to conventional jet fuel in terms of energy content and performance (Hileman & Stratton, 2014). FT fuels are produced from biomass through gasification and subsequent chemical synthesis, allowing for the conversion of a wide range of feedstocks, including municipal solid waste and lignocellulosic materials, into high-quality jet fuel. ATJ fuels are synthesized from alcohols, such as ethanol or butanol, through a process of dehydration, oligomerization, and hydrogenation, providing an alternative pathway for producing jet fuels from renewable resources (Chiaramonti et al., 2019).

Despite the promising potential of SAF, its large-scale adoption faces several challenges. One of the primary obstacles is the high production cost compared to conventional jet fuels. The production of SAF requires advanced technology and infrastructure, which are associated with higher capital and operational costs. Moreover, the availability and scalability of feedstocks are also limiting factors, as they need to be sourced sustainably without competing with food production or leading to deforestation (Lynch et al., 2017). Consequently, the current market share of SAF remains relatively small, with less than 0.1% of total aviation fuel consumption (Air Transport Action Group, 2020).

To overcome these barriers, various initiatives and policies have been implemented to promote the development and use of SAF. International organizations such as the International Civil Aviation Organization (ICAO) and the European Union have established frameworks and mandates to incentivize the production and uptake of SAF. For instance, ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) aims to achieve carbon-neutral growth in the aviation sector from 2020 by encouraging the use of SAF and other emission reduction measures (ICAO, 2019). The European Union's Renewable Energy Directive (RED) also sets targets for the integration of renewable energy sources, including SAF, in the transport sector (European Commission, 2018).

Furthermore, several airlines and aviation companies have initiated collaborations and investments in SAF production facilities to accelerate its commercialization. For example, major airlines like Lufthansa, KLM, and British Airways have conducted successful test flights using SAF blends, demonstrating its technical feasibility and compatibility with existing aircraft engines (Hasegawa et al., 2018). These initiatives indicate a growing industry commitment to adopting SAF as a viable alternative to conventional jet fuels.

The environmental benefits of SAF extend beyond CO₂ emission reductions. SAFs can also contribute to the reduction of non-CO₂ emissions, which have a significant impact on climate change and air quality. For instance, SAFs produce lower levels of sulfur oxides (SO_x) and particulate matter (PM) compared to traditional jet fuels, leading to a decrease in the formation of contrails and cirrus clouds that contribute to global warming (Moore et al., 2017). Additionally, the use of SAF can result in lower emissions of nitrogen oxides (NO_x), which are precursors to ozone formation and have adverse effects on human health and the environment (Elgowainy et al., 2014).

In conclusion, Sustainable Aviation Fuels (SAF) offer a promising solution for the aviation industry's environmental challenges. Their ability to significantly reduce lifecycle CO₂ emissions and other harmful pollutants makes them a key component in the sector's efforts to achieve sustainability goals. However, the widespread adoption of SAF is contingent on overcoming economic and logistical challenges, such as high production costs and feedstock availability. Through continued research, policy support, and industry collaboration, SAF has the potential to play a crucial role in the transition to a more sustainable aviation sector, contributing to global emission reduction efforts and improving air quality, particularly in urban areas like Skopje.

1.1.1 Types of SAF

Sustainable Aviation Fuels (SAF) encompass a variety of fuel types derived from renewable resources, each with unique characteristics and production methods. The most common types of SAF include Hydroprocessed Esters and Fatty Acids (HEFA), Fischer-Tropsch (FT) synthesized hydrocarbons, and Alcohol-to-Jet (ATJ) fuels.

Hydroprocessed Esters and Fatty Acids (HEFA):

HEFA fuels are the most widely used and commercially viable form of SAF. They are produced from lipid feedstocks, such as vegetable oils, animal fats, and used cooking oils. The production process involves hydrogenation and refining, which convert these oils into hydrocarbons similar to conventional jet fuels (Hileman & Stratton, 2014). HEFA fuels are compatible with existing aircraft engines and infrastructure, allowing for a seamless integration into the current aviation fuel supply chain. Due to their high energy content and performance characteristics, HEFA fuels are considered a near-term solution for reducing aviation emissions (International Air Transport Association, 2019)

Fischer-Tropsch (FT) Synthesized Hydrocarbons:

FT fuels are produced through a process that involves gasification of biomass feedstocks, such as municipal solid waste, agricultural residues, and lignocellulosic materials, followed by chemical synthesis. This process converts the feedstocks into a synthesis gas (syngas) composed of carbon monoxide and hydrogen, which is then catalytically converted into liquid hydrocarbons (de Jong et al., 2017). FT fuels have the advantage of being produced

from a wide range of feedstocks, including non-food biomass and waste materials, making them a versatile and sustainable option. Additionally, FT fuels have a high energy density and can be tailored to meet specific performance requirements for different types of aircraft (Hileman et al., 2010).

Alcohol-to-Jet (ATJ) Fuels:

ATJ fuels are synthesized from alcohols, such as ethanol or butanol, through a multi-step process that includes dehydration, oligomerization, and hydrogenation. This process converts the alcohols into hydrocarbons suitable for use as jet fuel (Chiaramonti et al., 2019). ATJ fuels offer an alternative pathway for producing SAF from renewable resources, particularly those derived from sugarcane, corn, and cellulosic biomass. One of the key advantages of ATJ fuels is the ability to use existing alcohol production infrastructure, which can potentially lower production costs and facilitate large-scale deployment. However, the energy content of ATJ fuels is typically lower than that of HEFA and FT fuels, which may affect their performance in certain applications (Staples et al., 2014).

Other Emerging SAF Pathways:

In addition to HEFA, FT, and ATJ fuels, there are several other emerging SAF pathways under development. These include Catalytic Hydrothermolysis Jet (CHJ) fuel, which uses a hydrothermal conversion process to produce jet fuel from fats, oils, and greases, and Power-to-Liquid (PtL) fuels, which are synthesized from CO₂ and renewable electricity through a process of electrolysis and chemical synthesis (Hannula & Reiner, 2019). These advanced pathways hold promise for further diversifying the SAF portfolio and enhancing the sustainability of aviation fuels.

1.1.2 Production Processes of SAF

The production processes for SAF vary depending on the feedstocks used and the desired end product. Each process involves a series of steps to convert raw materials into hydrocarbons that meet the stringent specifications required for aviation fuel.

Hydroprocessed Esters and Fatty Acids (HEFA):

The HEFA production process begins with the extraction and purification of oils from feedstocks such as vegetable oils, animal fats, and used cooking oils. These oils undergo a process called hydroprocessing, where they are reacted with hydrogen under high pressure and temperature in the presence of a catalyst. This step removes oxygen and converts the fatty acids into hydrocarbons similar to those found in conventional jet fuel (Hileman & Stratton, 2014). The resulting hydrocarbons are then distilled and refined to produce a final product that meets the necessary specifications for use in aircraft engines. HEFA production is relatively mature and has been commercialized by several companies, including Neste and Honeywell UOP (International Air Transport Association, 2019).

Fischer-Tropsch (FT) Synthesis:

FT synthesis is a multi-step process that begins with the gasification of biomass feedstocks, such as agricultural residues, municipal solid waste, or lignocellulosic materials. During gasification, the feedstocks are heated in the presence of oxygen or steam to produce syngas, a mixture of carbon monoxide and hydrogen (de Jong et al., 2017). The syngas is then cleaned and passed over a catalyst in a reactor, where it undergoes a series of chemical reactions to form liquid hydrocarbons. These hydrocarbons are further processed to produce jet fuel with the desired properties. The FT process can produce a wide range of hydrocarbon fuels, including jet fuel, diesel, and gasoline, depending on the catalyst and operating conditions used (Hileman et al., 2010).

Alcohol-to-Jet (ATJ):

The ATJ production process starts with the fermentation of biomass to produce alcohols, such as ethanol or butanol. These alcohols are then dehydrated to remove water and convert them into olefins, which are unsaturated hydrocarbons (Chiaramonti et al., 2019). The olefins undergo oligomerization, a process where small molecules combine to form larger hydrocarbons. Finally, the resulting hydrocarbons are hydrogenated to produce a final product that meets the specifications for jet fuel. The ATJ process is versatile and can use a variety of feedstocks, including sugarcane, corn, and cellulosic biomass, making it a promising pathway for producing SAF from renewable resources (Staples et al., 2014).

Catalytic Hydrothermolysis Jet (CHJ) Fuel:

CHJ fuel production involves the use of a hydrothermal process to convert fats, oils, and greases into hydrocarbons suitable for use as jet fuel. In this process, the feedstocks are subjected to high pressure and temperature in the presence of water, which causes the breakdown of triglycerides into fatty acids and glycerol. The fatty acids are then catalytically converted into hydrocarbons through a series of chemical reactions (Hannula & Reiner, 2019). The resulting fuel is refined to meet the required specifications for aviation use.

Power-to-Liquid (PtL) Fuels:

PtL fuels represent an innovative approach to SAF production, utilizing CO₂ and renewable electricity to synthesize liquid hydrocarbons. The process begins with the capture of CO₂ from industrial sources or direct air capture. The captured CO₂ is then combined with hydrogen produced through the electrolysis of water using renewable electricity. This mixture is converted into syngas, which is subsequently processed through FT synthesis or other catalytic processes to produce liquid hydrocarbons (Hannula & Reiner, 2019). PtL fuels have the potential to be a carbon-neutral solution, as the CO₂ used in their production is sourced from the atmosphere.

1.2 Benefits of SAF Compared to Conventional Fossil Fuels

Sustainable Aviation Fuels (SAF) offer a range of benefits over conventional fossil fuels, primarily due to their potential to significantly reduce the environmental impact of aviation. As the aviation industry is responsible for approximately 2-3% of global CO₂ emissions, transitioning to SAF is seen as a vital step toward achieving carbon neutrality and mitigating climate change (International Air Transport Association, 2019).

1.2.1 Reduction in Greenhouse Gas Emissions

One of the primary advantages of SAF is its potential to reduce lifecycle greenhouse gas (GHG) emissions by up to 80% compared to traditional jet fuels (de Jong et al., 2017). This reduction is achieved through the use of renewable feedstocks, such as waste oils,

agricultural residues, and non-food crops, which absorb CO₂ during their growth phase. This carbon uptake helps offset the emissions produced during the fuel's lifecycle, from production to combustion. In contrast, conventional fossil fuels release carbon that has been stored underground for millions of years, contributing to an overall increase in atmospheric CO₂ levels.

Furthermore, some advanced SAF pathways, such as Power-to-Liquid (PtL) fuels, can achieve near carbon neutrality by utilizing CO₂ captured directly from the atmosphere or industrial sources (Hannula & Reiner, 2019). By recycling CO₂ into fuel, PtL processes can significantly reduce the aviation sector's carbon footprint. The reduction in GHG emissions from SAF adoption can contribute to achieving international climate goals, such as the International Civil Aviation Organization's (ICAO) target of carbon-neutral growth from 2020 onwards (ICAO, 2019).

1.2.2 Improvement in Air Quality

Beyond CO₂ emissions, SAFs also contribute to a reduction in other harmful pollutants, improving air quality both globally and locally. Traditional jet fuels contain sulfur, which, when burned, produces sulfur oxides (SO_x) and contributes to the formation of fine particulate matter (PM) (Moore et al., 2017). These emissions have been linked to adverse health effects, such as respiratory and cardiovascular diseases, as well as environmental issues like acid rain.

SAFs, particularly Hydroprocessed Esters and Fatty Acids (HEFA) fuels, have lower sulfur content than conventional jet fuels, resulting in significantly reduced SO_x and PM emissions (International Air Transport Association, 2015). Additionally, the cleaner combustion properties of SAF lead to lower emissions of nitrogen oxides (NO_x), which are precursors to ground-level ozone and smog formation. By mitigating these pollutants, SAF can contribute to better air quality around airports and urban areas, which is particularly important in cities like Skopje that suffer from high levels of air pollution.

1.2.3 Enhanced Energy Security and Diversification

The use of SAF also offers benefits in terms of energy security and diversification. The aviation industry is currently heavily reliant on petroleum-based fuels, making it vulnerable

to fluctuations in oil prices and geopolitical tensions that can disrupt supply chains (Hileman et al., 2010). By incorporating SAF into the fuel mix, airlines can reduce their dependence on fossil fuels and enhance their resilience to market volatility.

SAF can be produced from a wide range of feedstocks, including agricultural residues, waste oils, and municipal solid waste, which are available in many regions around the world. This diversity in feedstocks not only contributes to a more secure energy supply but also provides an opportunity for rural development and job creation in areas involved in the production of biomass and waste collection (Elgowainy et al., 2012). The development of a domestic SAF industry can therefore support local economies while reducing reliance on imported fossil fuels.

1.2.4 Compatibility with Existing Infrastructure

Another significant benefit of SAF is its compatibility with existing aviation infrastructure. SAF can be blended with conventional jet fuel and used in existing aircraft engines without the need for modifications, which facilitates its adoption across the aviation sector (Hileman & Stratton, 2014). This "drop-in" characteristic of SAF means that it can be integrated into the current fuel supply chain, from refineries to airports, without requiring substantial changes to infrastructure or operational procedures.

This compatibility is crucial for the near-term implementation of SAF, as it allows airlines to gradually increase the proportion of SAF in their fuel mix, reducing their carbon footprint while continuing to use their current fleet. It also enables airports to supply SAF using existing fueling systems, making the transition to more sustainable fuels more cost-effective and feasible on a large scale.

1.2.5 Contribution to Circular Economy and Waste Management

SAF production can contribute to a circular economy by utilizing waste and residual materials that would otherwise be discarded. For example, HEFA fuels can be produced from used cooking oils and animal fats, while FT fuels can be synthesized from municipal solid waste and agricultural residues (de Jong et al., 2017). By converting waste into valuable fuel, SAF production helps reduce the environmental impact associated with waste disposal, such as landfill use and methane emissions.

Furthermore, SAF can play a role in promoting sustainable agricultural practices. The use of non-food crops and agricultural residues as feedstocks can provide additional income for farmers while avoiding competition with food production. This approach supports the development of a more sustainable and integrated bioeconomy, where waste and by-products are transformed into renewable energy sources (Lynch et al., 2017).

1.3 Impact of SAF on Emission Reduction and Air Quality

Sustainable Aviation Fuels (SAF) have a substantial impact on emission reduction and air quality improvement, addressing two of the most pressing environmental challenges in aviation. The aviation industry is a significant contributor to global greenhouse gas (GHG) emissions, responsible for approximately 2-3% of total anthropogenic CO₂ emissions (International Air Transport Association, 2019). SAFs, derived from renewable feedstocks like waste oils, agricultural residues, and non-food crops, offer a promising solution to reduce the sector's carbon footprint. Unlike conventional jet fuels, SAFs have the potential to reduce lifecycle GHG emissions by up to 80%, depending on the feedstock and production process used (de Jong et al., 2017). This reduction is achieved because the carbon absorbed by the biomass during its growth phase offsets the CO₂ emitted during fuel combustion, making SAF a carbon-neutral option over its entire lifecycle.

The role of SAF in emission reduction extends beyond just CO₂. Conventional jet fuels release sulfur oxides (SO_x) and particulate matter (PM) into the atmosphere during combustion, both of which have adverse effects on air quality and public health. SO_x emissions are particularly concerning as they contribute to the formation of fine PM, which can penetrate deep into the lungs and lead to respiratory and cardiovascular diseases (Moore et al., 2017). SAFs, especially those produced through processes like Hydroprocessed Esters and Fatty Acids (HEFA), have significantly lower sulfur content compared to conventional jet fuels. As a result, the use of SAF leads to a notable reduction in SO_x emissions, which directly improves air quality and reduces the associated health risks. The decrease in sulfur emissions also means that there is less formation of sulfate particles in the atmosphere, further contributing to cleaner air.

Furthermore, SAF has been shown to produce fewer particulate emissions during combustion. Particulate matter emissions from aviation can vary in size and composition,

with ultrafine particles posing the greatest health risks due to their ability to penetrate deep into the respiratory system. Research indicates that the use of SAF can reduce the number and mass of particulates emitted from aircraft engines. In a study conducted by Moore et al. (2017), it was found that using a 50% blend of HEFA in jet fuel resulted in a 50-70% reduction in particle emissions compared to conventional fuels. This reduction is primarily attributed to the cleaner combustion properties of SAF, which result in lower soot formation. This is particularly beneficial for airport regions where local air quality can be significantly affected by aircraft emissions, contributing to the overall improvement of air quality and reducing the exposure of nearby communities to harmful pollutants.

Another critical aspect of SAF's impact on emissions is its effect on nitrogen oxides (NO_x) emissions. NO_x is a precursor to ground-level ozone and smog formation, both of which have detrimental effects on human health and the environment. The combustion of conventional jet fuels at high temperatures in aircraft engines leads to the formation of NO_x, which can contribute to the development of respiratory problems and exacerbate conditions like asthma. While the reduction of NO_x emissions through SAF use is more complex and dependent on factors such as engine technology and operational conditions, SAF can contribute to lower NO_x emissions indirectly. This is because the reduced soot formation during SAF combustion can lead to a decrease in the formation of contrails and cirrus clouds, which have a net warming effect on the climate (Weyant et al., 2017). By reducing the formation of these cloud particles, SAF can help mitigate the overall radiative forcing associated with aviation, thereby contributing to climate change mitigation.

SAF also plays a role in reducing non-CO₂ climate impacts, such as contrail-induced cirrus cloudiness. Contrails are line-shaped clouds formed by aircraft engine exhaust and can persist to form cirrus clouds, which have a net warming effect on the Earth's atmosphere. The formation of contrails is influenced by the composition of aircraft emissions, particularly the presence of soot particles that act as nuclei for ice crystal formation. Studies have shown that the use of SAF, due to its lower aromatic and sulfur content, results in fewer soot particles and, consequently, a reduction in contrail formation (Moore et al., 2017). This reduction in contrail-induced cirrus clouds can lead to a decrease in the non-CO₂ climate impacts of aviation, making SAF an important tool in addressing both direct and indirect climate effects.

The overall impact of SAF on emission reduction and air quality is multi-dimensional. By significantly reducing CO₂ emissions, SAF helps the aviation industry align with global climate targets, such as those set by the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) (ICAO, 2019). This scheme aims for carbon-neutral growth in international aviation from 2020 onwards, and SAF plays a critical role in achieving this goal. In addition to CO₂, the reduction in other pollutants like SO_x, PM, and potentially NO_x through SAF adoption can lead to substantial improvements in air quality, particularly in urban areas and regions near airports where air pollution is a significant concern.

However, the extent of SAF's impact on emission reduction and air quality also depends on the scale of its adoption and the feedstocks used. While the potential benefits are clear, challenges such as the current high production costs of SAF, limited feedstock availability, and the need for supportive regulatory frameworks must be addressed to facilitate widespread adoption. As the aviation industry continues to grow, the adoption of SAF will be crucial in mitigating its environmental impact and improving air quality, especially in cities like Skopje, where air pollution is a critical issue.

In conclusion, the impact of SAF on emission reduction and air quality is substantial and offers a pathway toward a more sustainable aviation sector. By reducing lifecycle GHG emissions, cutting down on SO_x and PM emissions, and potentially reducing NO_x and contrail formation, SAF can play a pivotal role in addressing both climate change and local air quality issues. The transition to SAF represents a significant step towards achieving the dual goals of reducing the aviation industry's carbon footprint and improving public health outcomes through better air quality.

1.4 Environmental and Regulatory Frameworks Influencing SAF Adoption

The adoption of Sustainable Aviation Fuels (SAF) is significantly influenced by a complex interplay of environmental and regulatory frameworks designed to reduce the aviation industry's carbon footprint and promote sustainable practices. As concerns about climate change and air quality intensify, regulatory bodies and international organizations have established a series of policies and guidelines aimed at accelerating the development and integration of SAF into the aviation sector. These frameworks not only set targets for

emission reductions but also create incentives and mechanisms to encourage the adoption of alternative fuels.

One of the most influential global regulatory frameworks is the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Introduced in 2016, CORSIA aims to achieve carbon-neutral growth in international aviation from 2020 onwards by requiring airlines to offset any increase in CO₂ emissions above 2020 levels (ICAO, 2019). Under CORSIA, airlines are encouraged to use SAF to reduce their carbon emissions, as SAF can be counted towards meeting their offsetting requirements. CORSIA establishes a standardized methodology for calculating the lifecycle emissions of SAF, ensuring that only fuels meeting stringent sustainability criteria are recognized. This framework has been a driving force in creating a market for SAF, providing airlines with a clear incentive to invest in and adopt these fuels.

In addition to CORSIA, regional frameworks such as the European Union's Renewable Energy Directive (RED) have played a pivotal role in promoting SAF adoption. The updated RED II, which came into effect in 2021, sets ambitious targets for renewable energy use in the transport sector, including aviation. It mandates that member states achieve a minimum share of renewable energy in transport, with a specific focus on advanced biofuels like SAF (European Commission, 2018). The directive also includes specific sustainability criteria for biofuels, requiring that they deliver substantial greenhouse gas savings and avoid adverse impacts on land use and biodiversity. These criteria ensure that SAF not only reduces emissions but also meets broader environmental and social sustainability goals.

National governments have also introduced policies to support the development and use of SAF. For example, in the United States, the Renewable Fuel Standard (RFS) program requires a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil, or jet fuel (U.S. Environmental Protection Agency, 2020). The RFS includes provisions for aviation biofuels, providing financial incentives for their production and use. Similarly, countries like Norway and Sweden have introduced mandates requiring a specific percentage of aviation fuel to be biofuel, creating a direct demand for SAF (SkyNRG, 2020). These national policies complement international frameworks by providing targeted support and incentives at the country level.

Another important aspect of the regulatory environment influencing SAF adoption is the implementation of carbon pricing mechanisms. Carbon pricing, through instruments such as carbon taxes or emissions trading systems (ETS), places a monetary value on carbon emissions, thereby incentivizing airlines to reduce their carbon footprint (World Bank, 2020). For instance, the European Union Emissions Trading System (EU ETS) requires airlines operating in the EU to purchase allowances for their emissions, effectively increasing the cost of fossil fuel use (European Commission, 2020). By making SAF exempt from or subject to lower carbon pricing, these mechanisms can encourage airlines to switch to lower-carbon alternatives. This financial incentive is crucial for bridging the cost gap between SAF and conventional jet fuels, which is currently one of the main barriers to widespread SAF adoption.

In addition to regulatory measures, several international initiatives and partnerships have been established to support the research, development, and deployment of SAF. For instance, the International Air Transport Association (IATA) has launched the "Fly Net Zero" initiative, aiming to achieve net-zero carbon emissions by 2050, with SAF identified as a key component of this strategy (IATA, 2021). Similarly, the Commercial Aviation Alternative Fuels Initiative (CAAIFI) works to advance the development and commercialization of SAF through collaboration between airlines, government agencies, fuel producers, and other stakeholders (CAAIFI, 2021). These initiatives play a vital role in facilitating knowledge sharing, technical standardization, and market development for SAF.

Environmental frameworks also emphasize the importance of sustainability criteria for SAF feedstocks. Ensuring that the production of SAF does not lead to negative environmental impacts, such as deforestation, loss of biodiversity, or competition with food crops, is crucial for its long-term sustainability. Organizations like the Roundtable on Sustainable Biomaterials (RSB) have developed certification schemes to ensure that SAF meets high environmental and social standards (RSB, 2020). These certification systems provide a way to verify that SAF is produced sustainably, offering transparency and assurance to airlines and consumers about the environmental benefits of using SAF.

Despite the progress made, there are still challenges in fully integrating SAF into the aviation fuel mix. The high cost of SAF production, limited feedstock availability, and the need for significant investment in production infrastructure are some of the barriers that

regulatory frameworks aim to address. Policies that provide financial incentives, such as subsidies, grants, and tax credits, can help offset the higher costs associated with SAF and stimulate investment in production capacity (Staples et al., 2018). Moreover, clear and consistent regulatory support is needed to create a stable market environment that encourages long-term investment in SAF.

In summary, the adoption of SAF is heavily influenced by a range of environmental and regulatory frameworks at international, regional, and national levels. Frameworks like ICAO's CORSIA and the EU's Renewable Energy Directive provide the necessary policy support and incentives to encourage airlines to transition to SAF, while carbon pricing mechanisms and sustainability certification systems ensure that SAF delivers genuine environmental benefits. Continued collaboration between governments, industry, and international organizations is essential to overcome the remaining challenges and scale up SAF production and use, thereby contributing to the aviation industry's efforts to reduce its environmental impact.

1.5 Review of Existing Literature on SAF and Emission Reduction

The role of Sustainable Aviation Fuels (SAF) in reducing emissions has been the subject of extensive research and discussion in recent years. The literature on SAF and emission reduction spans various aspects, including lifecycle analysis, the environmental impact of SAF compared to conventional fuels, and the potential for SAF to contribute to the decarbonization of the aviation industry. This section reviews key findings from existing literature, highlighting the potential benefits and challenges associated with SAF adoption.

One of the primary focuses of SAF research is its ability to reduce lifecycle greenhouse gas (GHG) emissions. Studies consistently show that SAF can lead to significant reductions in GHG emissions when compared to conventional jet fuels. de Jong et al. (2017) conducted a comprehensive lifecycle analysis of renewable jet fuel production, finding that SAF can reduce GHG emissions by up to 80% depending on the feedstock and production pathway used. This substantial reduction is primarily due to the renewable nature of SAF feedstocks, such as waste oils, agricultural residues, and non-food crops, which absorb CO₂ during their growth phase, thereby offsetting emissions produced during fuel production and combustion. Similarly, Staples et al. (2014) examined the

lifecycle emissions of various SAF pathways, concluding that advanced biofuels, such as Hydroprocessed Esters and Fatty Acids (HEFA) and Fischer-Tropsch (FT) fuels, offer significant emissions savings over their lifecycle.

The reduction in non-CO₂ emissions is another critical area explored in the literature. Conventional jet fuels produce emissions such as sulfur oxides (SO_x), particulate matter (PM), and nitrogen oxides (NO_x), which have adverse effects on air quality and contribute to global warming. Moore et al. (2017) found that blending SAF with conventional jet fuel can result in a 50-70% reduction in particulate emissions. This reduction is particularly important in regions around airports where local air quality can be significantly affected by aircraft emissions. The study demonstrated that the lower aromatic and sulfur content of SAF leads to cleaner combustion, producing fewer soot particles and thereby reducing the formation of contrails and cirrus clouds, which have a net warming effect on the climate. Additionally, Armstrong et al. (2016) highlighted that the use of SAF can lead to a reduction in sulfur-related emissions, further improving air quality and mitigating the environmental impact of aviation.

While the environmental benefits of SAF are well-documented, the literature also addresses the challenges and limitations of its large-scale adoption. One of the main challenges is the high cost of SAF production. Currently, SAF is more expensive to produce than conventional jet fuels, primarily due to the costs associated with feedstock cultivation, processing, and the production infrastructure required (Elgowainy et al., 2012). This price differential poses a barrier to widespread adoption, as airlines operate in a highly cost-sensitive market. Various studies, including that by de Jong et al. (2017), suggest that policy measures such as subsidies, carbon pricing, and mandates are essential to make SAF cost-competitive with traditional fuels and to stimulate demand.

Another challenge discussed in the literature is feedstock availability and sustainability. While SAF can be produced from a variety of feedstocks, ensuring a sustainable and sufficient supply of these feedstocks is crucial for scaling up SAF production. The competition for land, water, and other resources between food production and biofuel crops is a concern, as highlighted by Tilman et al. (2009). To mitigate this, researchers advocate for the use of waste and residue materials as feedstocks, such as used cooking oil, agricultural residues, and municipal solid waste, which do not compete with food

production and have a lower environmental impact.

The literature also emphasizes the importance of regulatory and policy support in facilitating the adoption of SAF. Regulatory frameworks such as the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and the European Union's Renewable Energy Directive (RED) play a vital role in creating incentives and setting standards for SAF use (ICAO, 2019; European Commission, 2018). According to a study by Pavlenko et al. (2019), supportive policies and regulatory measures are critical for reducing the cost of SAF, encouraging investment in production infrastructure, and establishing a market for sustainable fuels. These measures include mandates for blending SAF with conventional fuels, tax incentives, and support for research and development in advanced biofuel technologies.

Recent literature also explores the long-term potential of SAF in achieving the aviation industry's decarbonization goals. The International Air Transport Association (IATA) has set ambitious targets for reducing aviation emissions, including achieving net-zero carbon emissions by 2050 (IATA, 2021). SAF is considered a key component in meeting these targets, as it offers a feasible pathway to decarbonize aviation without the need for immediate, large-scale changes to aircraft technology and infrastructure. A study by Corsatea and Marchisio (2021) suggests that with appropriate policy support and technological advancements, SAF could account for a significant share of aviation fuel consumption by mid-century, contributing to the sector's transition to a low-carbon future.

In summary, the existing literature on SAF and emission reduction presents a compelling case for the adoption of SAF as a means to reduce the aviation industry's environmental impact. Research demonstrates that SAF can substantially lower lifecycle GHG emissions and reduce non-CO₂ pollutants, thereby contributing to climate change mitigation and improved air quality. However, challenges such as high production costs, feedstock availability, and the need for supportive regulatory frameworks must be addressed to realize the full potential of SAF. Continued research, investment, and policy support are crucial to overcoming these barriers and promoting the large-scale adoption of SAF in the aviation sector.

2 Policy Implications and Strategies for SAF Implementation

2.1 Policy Measures to Promote SAF in Skopje

Effective policy implementation for Sustainable Aviation Fuel (SAF) in Skopje demands clear, targeted, and achievable measures. Given that SAF can only be blended up to 50 % with conventional aviation fuels, with current realistic mixtures at around 0.5 % to 2 % (IATA, 2022), policies must directly address incentives to gradually increase these blending rates. Regulatory frameworks such as the EU Renewable Energy Directive II (RED II) set clear guidelines and mandatory targets for member states, which could serve as benchmarks for Skopje's SAF implementation strategy (European Commission, 2018).

Financial incentives, including tax relief and subsidies, represent primary policy measures to encourage airlines to transition towards SAF. According to the International Air Transport Association, direct financial support significantly boosts adoption rates of SAF among airlines, particularly when production costs remain high (IATA, 2022). Thus, modifying the Macedonian Law on Excise Duties to incorporate tax exemptions specifically for airlines using SAF can incentivize faster adoption within Skopje's international airport operations (Official Gazette of RNM, 2022).

Furthermore, the Macedonian government could establish dedicated public-private partnerships (PPP) aimed at developing local SAF production facilities. Studies conducted by ICAO (2021) indicate that successful SAF implementation strategies globally often involve partnerships between governments and private enterprises, combining financial resources, technological knowledge, and regulatory support to build infrastructure needed for production and distribution. Such partnerships could significantly reduce the initial investment risk and stimulate local economic development.

A policy framework emphasizing mandatory SAF usage quotas for airlines operating at Skopje International Airport can also accelerate market penetration. European experiences, particularly in Norway and the Netherlands, show that regulatory mandates effectively boost initial demand and stimulate long-term production capacity (Norwegian Environment Agency, 2020). By setting phased targets for SAF blending rates, Skopje could realistically achieve meaningful utilization levels, thus aligning with EU sustainability goals.

Education and capacity-building programs constitute critical supporting measures for successful SAF implementation. Research emphasizes the need to increase awareness among aviation stakeholders about the environmental and economic benefits of SAF (ATAG, 2020). Creating targeted training programs and stakeholder workshops, supported by government policies, would enhance understanding, acceptance, and commitment among key stakeholders, including airlines, airport operators, and fuel suppliers in Skopje.

Transparency and clear communication about SAF policies and their intended environmental benefits can improve public acceptance and stakeholder cooperation. Implementing standardized reporting procedures, as suggested in ICAO guidelines (ICAO, 2021), would facilitate transparency regarding SAF blending levels and associated emission reductions. This transparency can foster trust, ensure accountability, and further encourage adoption by demonstrating tangible environmental benefits.

Moreover, aligning local regulations with international standards such as those outlined by ASTM D7566 specifications for sustainable aviation fuels ensures compatibility and safety in aviation operations (ASTM International, 2020). Incorporating these international technical standards within Skopje's regulatory framework will provide airlines confidence in the quality and reliability of SAF, facilitating broader market acceptance.

Market analyses conducted by global consulting firms underline the importance of establishing long-term procurement agreements between airlines and SAF producers to secure production scale and reduce costs (McKinsey & Company, 2021). Policy measures should, therefore, include facilitation of long-term contracts, supported by governmental financial guarantees, reducing market uncertainties for producers and users alike.

In addition to financial and regulatory support, providing grants for research and innovation in SAF technology can address local infrastructural and logistical challenges. Local universities and research institutes could be incentivized through targeted research funding to focus on optimizing SAF production and exploring alternative feedstocks, thus reducing dependency on imported raw materials and fostering innovation locally (European Commission, 2019).

Implementing effective monitoring systems, guided by established EU practices such as the EU ETS monitoring protocols (European Commission, 2021), will be critical. These

systems would track the actual use of SAF, verify compliance with mandatory blending levels, and measure environmental outcomes, providing essential data to assess the effectiveness of implemented policy measures.

Finally, integrating these policy measures within a broader national strategic framework aligned with the National Strategy for Energy Development (Ministry of Economy RNM, 2020) would ensure coherence and enhance overall policy effectiveness. This integration ensures that SAF policies complement wider national sustainability objectives, driving comprehensive and sustained adoption of environmentally friendly aviation practices in Skopje.

2.1.1 Incentives for SAF Production and Use

Establishing effective incentives for Sustainable Aviation Fuel (SAF) production and usage is crucial to accelerate adoption in Skopje. According to the International Air Transport Association (IATA, 2021), current SAF production remains limited due to significant cost barriers and lack of targeted incentives. Governments worldwide are implementing regulatory and fiscal tools to stimulate the SAF market, setting clear precedents for policy frameworks. The Macedonian government could similarly apply international best practices such as direct subsidies, tax relief, and incentives for both production and airline adoption. This aligns with EU's Renewable Energy Directive II (RED II), advocating substantial state incentives for sustainable aviation practices (European Commission, 2018).

Financial incentives represent a fundamental driver for SAF integration. Reducing taxes on SAF compared to fossil jet fuels is one effective policy measure already proven successful in European contexts. For example, Norway introduced a reduced aviation fuel tax specifically aimed at promoting SAF usage, significantly boosting airlines' adoption rates (Norwegian Environment Agency, 2020). Implementing similar measures in North Macedonia, via adjustments in the Law on Excise Duties (Official Gazette of RNM, 2022), could effectively encourage the aviation sector in Skopje to increase their SAF blending ratios. Moreover, financial support could lower SAF's market-entry barriers and thus motivate airlines to consistently use higher SAF proportions.

The use of direct government subsidies is another critical incentive mechanism. Research conducted by McKinsey & Company (2021) highlights that direct subsidies for SAF

production significantly reduce upfront investment risks, thereby increasing industry confidence and production capacity. By offering targeted subsidies to SAF producers operating in or near Skopje, the Macedonian government can actively promote local SAF production, creating a stable and predictable market environment. This strategy directly aligns with guidelines established in the EU Aviation Strategy, which emphasizes government support in developing sustainable aviation fuel markets (European Commission, 2015). Ensuring stability and predictability through subsidies helps attract necessary private-sector investments in SAF production infrastructure.

Public-private partnerships (PPP) represent another effective incentive structure supporting SAF adoption. The International Civil Aviation Organization (ICAO, 2021) strongly recommends PPP as a best practice, leveraging private-sector expertise and public-sector resources. Successful examples include the SkyNRG project in the Netherlands, where government support through PPP significantly increased SAF production capacity and market readiness (ICAO, 2021). Similarly, establishing a structured PPP approach in Skopje could engage local aviation stakeholders, regional authorities, and private investors to build necessary infrastructure. This collaboration not only facilitates local SAF production but also addresses logistical challenges, enhancing the feasibility of sustained SAF use in aviation operations within the Macedonian context.

Implementing blending mandates represents a regulatory incentive critical for accelerating SAF integration. Regulatory approaches requiring specific percentages of SAF blending in jet fuel are increasingly recognized as effective (ATAG, 2020). For instance, France introduced a legal mandate requiring 1 % SAF blend by 2022, progressively increasing annually (French Ministry of Ecological Transition, 2021). Adopting such mandatory blending rates in Skopje's aviation fuel market can guarantee sustained demand for SAF and encourage fuel suppliers to develop necessary production capabilities. Regulatory mandates provide market certainty, motivating producers to scale up operations, and airlines to incorporate higher percentages of sustainable fuels to comply with national regulations.

Investment incentives for research and innovation are equally important. EU Horizon Europe funding programs provide substantial support for sustainable aviation fuel research, highlighting the strategic importance of innovation funding (European

Commission, 2019). Introducing similar funding mechanisms in North Macedonia, targeted at academic and research institutions, could foster local expertise and technological advancements in SAF production. Funding research focused on alternative feedstocks, production processes, and improved logistics can reduce dependency on imported raw materials, enhance economic sustainability, and position Skopje as a regional leader in SAF innovation. Additionally, research grants can facilitate collaborative projects between academia and industry, thus accelerating practical implementation and commercialization of SAF technologies.

Market-based incentives such as carbon pricing or emissions trading systems (ETS) represent another crucial approach. Under the EU ETS framework, airlines purchasing SAF benefit from reduced compliance costs due to lower emissions (European Commission, 2021). Implementing a similar carbon pricing mechanism in Skopje could encourage airlines operating locally to prioritize SAF usage, as it reduces their financial liabilities associated with carbon emissions. This approach aligns economic incentives directly with environmental performance, creating a powerful motivation for airlines to adopt higher SAF blending rates. Such mechanisms provide clear financial advantages, significantly influencing airline purchasing decisions in favor of sustainable fuel alternatives, thus supporting broader environmental policy objectives.

Supportive legislative frameworks for securing long-term supply agreements between airlines and SAF producers are essential incentives. According to ICAO (2021), long-term purchase agreements substantially reduce investment risks for producers, ensuring stable demand and predictable revenue streams. Governments can facilitate these agreements through legislative and regulatory frameworks, encouraging airlines operating at Skopje International Airport to commit to fixed-term SAF procurement contracts. This guarantees a reliable market for SAF producers and secures airlines' long-term access to sustainable fuels at stable prices. The stability provided by these agreements incentivizes significant investment into SAF production capacity, helping achieve economies of scale that gradually lower production costs over time.

Transparency incentives through regular reporting and monitoring systems also enhance SAF usage. The EU recommends rigorous monitoring and transparent reporting standards within the EU ETS and RED II frameworks (European Commission, 2018, 2021). Adopting

similar standards in Skopje's aviation sector would establish transparency, enabling precise tracking of SAF consumption levels and environmental outcomes. Transparent reporting not only builds public trust but also provides airlines with clear evidence of their environmental contributions, potentially improving their market image and attracting environmentally conscious customers. This incentive fosters market differentiation, rewarding airlines that proactively integrate higher SAF proportions into their operations.

Educational incentives through training and capacity-building programs significantly impact stakeholder engagement. ATAG (2020) underscores the importance of targeted educational campaigns to enhance aviation stakeholders' understanding of SAF benefits and opportunities. Implementing comprehensive educational programs in Skopje, including workshops, training modules, and public awareness initiatives, can significantly increase stakeholder acceptance. Awareness of SAF's environmental advantages, coupled with clear communication about available financial and regulatory incentives, improves stakeholder cooperation. Education and outreach also prepare airlines, fuel suppliers, and regulators to effectively navigate the transition toward sustainable aviation practices, further facilitating SAF integration.

Alignment of local SAF incentives with broader national sustainability strategies ensures policy coherence and effectiveness. Integrating SAF-focused incentives within North Macedonia's National Energy Strategy (Ministry of Economy RNM, 2020) can reinforce broader national objectives. This integrated approach ensures SAF incentives complement existing sustainability goals across energy, transport, and environmental sectors. By embedding SAF incentives within national policy frameworks, Skopje can achieve broader support, sustained funding, and policy consistency, which are essential for the long-term success of SAF initiatives. Strategic integration of SAF incentives within national frameworks ensures sustainability measures are comprehensive, well-coordinated, and effectively implemented across all relevant sectors.

2.1.2 Regulatory Frameworks for SAF Integration

To effectively integrate Sustainable Aviation Fuel (SAF) into the aviation sector in Skopje, a robust regulatory framework aligned with international standards must be established. The European Union provides significant regulatory guidance, primarily through the

Renewable Energy Directive (RED II), which mandates the increased use of renewable energy sources, including SAF, within transportation sectors (European Commission, 2018). By aligning local policies in Skopje with RED II, North Macedonia could ensure consistent regulatory standards with EU practices, facilitating market entry and regional cooperation.

The European Aviation Safety Agency (EASA) also sets clear regulatory standards governing SAF utilization, focusing heavily on operational safety and fuel quality requirements. EASA ensures that SAF meets strict international fuel certification standards, notably ASTM D7566, thus maintaining aviation safety and operational reliability (EASA, 2019). Adopting these stringent certification standards in Macedonian aviation regulations could ensure safe, standardized, and reliable integration of SAF within local aviation operations at Skopje International Airport.

The International Civil Aviation Organization (ICAO) additionally provides a comprehensive regulatory framework designed to assist member states in integrating SAF into national aviation sectors. ICAO guidelines emphasize harmonization, promoting consistency among national regulations, thereby reducing barriers to international aviation (ICAO, 2021). Incorporating ICAO's regulatory recommendations within the Macedonian national aviation law could streamline SAF integration processes, allowing airlines operating from Skopje to seamlessly participate in global aviation sustainability initiatives.

Local regulatory measures must include explicit mandates defining minimum blending requirements for SAF in aviation fuels. Research indicates regulatory mandates significantly influence the willingness of airlines and fuel suppliers to adopt SAF, fostering stable market demand and production predictability (ATAG, 2020). Skopje could introduce legally binding SAF blending targets within national aviation fuel regulations, incrementally raising the mandated blending percentages over defined periods to stimulate consistent growth in demand and production.

Furthermore, establishing specific regulatory incentives, such as reduced landing fees or airport charges for airlines utilizing higher SAF blends, could enhance integration. Such regulatory incentives are already effective in European aviation hubs, creating direct economic benefits and encouraging SAF adoption (Norwegian Environment Agency,

2020). Embedding these financial incentives into Macedonian aviation regulatory frameworks would directly encourage airlines at Skopje International Airport to prioritize SAF usage, effectively aligning environmental objectives with economic incentives.

Comprehensive regulatory monitoring mechanisms are vital to ensuring compliance with SAF integration targets. The European Union's Emissions Trading System (EU ETS) serves as a successful regulatory model, establishing transparent and accountable procedures for verifying SAF usage and emissions reductions (European Commission, 2021). Implementing a similar regulatory framework in Skopje would facilitate accurate tracking of SAF utilization, holding airlines accountable for meeting environmental and sustainability obligations, thus enhancing transparency and public trust.

Clear regulatory provisions on SAF feedstock sustainability criteria are essential to prevent potential environmental and social adverse effects. The RED II directive provides detailed criteria for evaluating SAF feedstocks, ensuring they deliver genuine greenhouse gas emission reductions without compromising biodiversity or land use (European Commission, 2018). Incorporating similar stringent sustainability criteria within Macedonian regulations ensures that SAF production in Skopje aligns closely with EU environmental protection standards, avoiding unintended ecological impacts and preserving public confidence.

Regulatory frameworks must also provide guidelines facilitating the establishment of local SAF production facilities, addressing administrative barriers and ensuring streamlined permitting procedures. International research identifies simplified regulatory procedures and clear guidelines as crucial for fostering local SAF infrastructure development (McKinsey & Company, 2021). By implementing transparent, efficient regulatory processes for facility licensing, Skopje could attract both local and international investors, accelerating regional production capabilities and market readiness for SAF.

Harmonizing local aviation regulatory frameworks with the broader European aviation network remains critical. The Single European Sky (SES) initiative provides regulatory frameworks aiming at streamlining air navigation and reducing aviation emissions through improved operational efficiency (European Commission, 2020). Incorporating the SES framework principles into Macedonian aviation regulations could complement SAF usage,

further reducing overall aviation emissions and promoting cohesive regional aviation policies focused on sustainability.

Training and capacity-building regulatory measures, mandated through national legislation, could ensure effective stakeholder engagement in SAF implementation. Regulatory frameworks promoting regular educational initiatives and industry training programs are effective in facilitating stakeholders' compliance with new environmental regulations and standards (ATAG, 2020). Establishing legally mandated training and educational programs within Macedonian aviation regulations would significantly enhance stakeholders' capabilities and readiness to adopt SAF, thereby facilitating smooth integration.

Legal frameworks ensuring long-term agreements between airlines and SAF producers significantly improve market predictability. International analyses emphasize long-term contracts as effective regulatory tools for stabilizing SAF markets, encouraging sustainable and economically viable production capacities (ICAO, 2021). By incorporating provisions facilitating and protecting these agreements in Macedonian commercial and aviation legislation, the government would encourage airlines and producers to engage confidently in long-term SAF commitments, thereby stabilizing and growing the local SAF market.

Regular reviews and updates of regulatory frameworks are essential to reflect technological advances and evolving international standards. European regulatory models highlight the necessity of periodic policy evaluations, ensuring regulations remain relevant and responsive to new developments in SAF technologies and markets (European Commission, 2021). Institutionalizing regulatory review mechanisms within Macedonian aviation regulations ensures continuous improvement, adaptability, and effective response to emerging challenges and opportunities in SAF integration.

Implementing clear penalties for non-compliance with SAF-related regulations could enhance regulatory effectiveness. European aviation regulations clearly outline penalties to ensure strict adherence, effectively incentivizing compliance among industry stakeholders (European Commission, 2021). Establishing comparable enforcement mechanisms in North Macedonia's aviation regulatory framework would significantly increase stakeholder accountability, thus effectively maintaining consistent and meaningful adoption of SAF within Skopje's aviation sector. Furthermore, clear regulations ensuring

consumer transparency regarding airlines' SAF usage can positively influence public awareness and market dynamics. International studies consistently indicate transparency measures as critical for enhancing consumer choice and promoting sustainable market practices (ATAG, 2020). Macedonian aviation regulations could mandate clear consumer reporting on airline SAF usage, empowering passengers to make environmentally informed decisions, consequently reinforcing market-driven incentives for higher SAF adoption among airlines operating in Skopje.

Finally, integrating local regulatory frameworks into broader national environmental legislation ensures policy coherence and comprehensive sustainability benefits. Coordinating aviation-specific SAF regulations with North Macedonia's national environmental protection laws guarantees a holistic regulatory approach, aligning aviation sector sustainability efforts with broader national environmental objectives (Ministry of Environment RNM, 2020). Such integration ensures that SAF integration contributes significantly to Macedonia's overall sustainability strategy, ensuring maximum environmental and economic benefits from aviation sector advancements.

2.2.1 Government Initiatives and Support Mechanisms

Government initiatives are fundamental in facilitating the integration and advancement of Sustainable Aviation Fuels (SAF) in aviation. Effective government involvement typically combines regulatory, financial, and institutional mechanisms aimed at promoting SAF adoption, thereby enhancing sustainability in the aviation industry (ICAO, 2021). In Skopje, governmental support could similarly provide a structured approach, driving industry adoption through strategic legislation and financial support. Government policies can significantly lower initial investment risks, fostering a competitive and stable market environment that encourages local production and sustained use of SAF (European Commission, 2018).

Establishing dedicated financial mechanisms, such as subsidies or grants, represents a crucial role of government support. Subsidies specifically targeted at producers can significantly mitigate high initial investment costs associated with establishing SAF production facilities (ATAG, 2020). European experiences demonstrate that targeted financial support measures, notably in Germany and Sweden, have successfully

accelerated the SAF industry's growth by providing producers with stability and predictability (European Commission, 2019). Replicating these approaches in North Macedonia through specific government-led funding initiatives could similarly boost local production capacity and enhance market readiness for SAF in Skopje.

National aviation legislation must integrate clear policies promoting mandatory blending quotas for SAF, effectively driving industry-wide adoption. The success of blending mandates in European contexts, such as in France and Norway, provides clear evidence that structured regulatory frameworks significantly boost market penetration (Norwegian Environment Agency, 2020). In the Macedonian context, similar policy-driven mandates could gradually increase blending requirements at Skopje International Airport, providing consistent market demand and incentivizing local SAF producers to scale up production. Clear and legally binding mandates also offer transparency, helping build stakeholder confidence and sustained commitment to SAF integration.

Government support can further be realized through public-private partnerships (PPP), combining state resources with private-sector expertise to expand SAF infrastructure. Globally, PPP models have proven highly effective, notably in the Netherlands through initiatives such as the SkyNRG SAF plant (ICAO, 2021). The Macedonian government could initiate similar partnerships, leveraging private-sector resources and expertise to efficiently establish production facilities and distribution networks. PPP structures effectively distribute risks, allowing the government to encourage local economic growth while simultaneously advancing national sustainability objectives within the aviation sector.

Additionally, governments play a vital role in creating clear regulatory frameworks that facilitate streamlined administrative processes. Complex licensing procedures can significantly impede SAF infrastructure development, slowing down market entry and production ramp-up (McKinsey & Company, 2021). By simplifying permitting processes and providing clear regulatory guidelines, the Macedonian government can reduce bureaucratic obstacles, accelerating the establishment of local SAF production facilities. Streamlined administrative procedures increase investment attractiveness, incentivizing both domestic and international companies to invest in Skopje's aviation sustainability projects.

Investment in research and development (R&D) is another essential area where government support is crucial. Strategic funding initiatives for SAF-focused research can stimulate technological innovation, improving feedstock diversity and production processes (European Commission, 2019). Governments in Europe routinely provide funding through programs like Horizon Europe, significantly accelerating advancements in SAF technologies (European Commission, 2019). North Macedonia could similarly introduce dedicated research grants targeting universities and research institutions, enhancing local scientific capabilities and fostering domestic innovation that supports sustainable aviation initiatives in Skopje.

Government-led education and capacity-building initiatives represent critical supporting mechanisms. Effective stakeholder training programs significantly increase SAF adoption by improving awareness and technical understanding among aviation industry stakeholders (ATAG, 2020). Macedonian authorities could establish legally mandated education and training initiatives aimed at enhancing stakeholder readiness and operational capacity to adopt SAF technologies. Increased knowledge and operational expertise ensure smooth industry transition, directly supporting effective policy implementation and sustained stakeholder engagement throughout the SAF integration process.

Government-driven transparency measures can further strengthen stakeholder confidence and public trust. Clear reporting standards, similar to those mandated by the European Union's Emissions Trading System (ETS), improve transparency regarding SAF use, emissions reductions, and industry compliance (European Commission, 2021). Adopting similar transparency and reporting mechanisms in Skopje would enhance accountability, providing airlines and producers clear incentives to prioritize SAF adoption. Transparency effectively communicates environmental benefits, thereby strengthening market credibility and promoting informed stakeholder participation.

Implementing economic incentives through taxation adjustments represents another effective governmental mechanism. Reduced taxes or exemptions specifically for SAF use can substantially reduce airlines' operating costs, incentivizing sustained SAF adoption (Norwegian Environment Agency, 2020). Incorporating these economic incentives into national tax regulations would encourage airlines operating from Skopje to increase their

SAF blending levels. These targeted fiscal incentives align economic benefits with environmental objectives, fostering consistent industry commitment and facilitating long-term adoption of SAF practices in aviation.

Government involvement through the development of specific SAF-related national strategies can ensure coherent policy implementation. Aligning aviation-specific SAF goals with broader national energy and environmental strategies ensures consistent and mutually reinforcing policy outcomes (Ministry of Economy RNM, 2020). Integrating SAF adoption into national sustainability and climate strategies enhances the coherence of governmental actions and leverages cross-sectoral support. Such strategic integration ensures comprehensive governmental commitment and resource allocation, significantly enhancing the effectiveness of SAF-related initiatives in Skopje.

Provision of government guarantees for long-term procurement agreements between airlines and SAF producers also constitutes essential government support. Legal frameworks protecting long-term contracts provide stability and reduce investment risks, significantly boosting market confidence among producers and airlines alike (ICAO, 2021). Establishing clear legislative guidelines for contractual agreements would stabilize local market dynamics, encourage sustainable production capacities, and ensure consistent and long-term SAF adoption in Skopje's aviation market.

Governments can significantly influence consumer behavior by requiring transparency in airlines' marketing related to SAF use. Regulations mandating public disclosure of airlines' SAF usage empower consumers, allowing them to make informed environmentally-conscious choices (ATAG, 2020). Such consumer-focused regulations in Skopje could create market-driven incentives for airlines to enhance their environmental performance. Public transparency regarding SAF integration encourages airlines to competitively increase their sustainable practices, thus contributing significantly to broader environmental sustainability objectives.

Effective government support also includes active participation in international cooperative frameworks and initiatives. Participation in global sustainability partnerships, such as ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), provides North Macedonia opportunities to access international expertise and financial

resources (ICAO, 2021). Active governmental engagement in these global initiatives can significantly boost local capacity for SAF integration, aligning Skopje's aviation sector with international standards and practices, and thereby facilitating broader global collaboration.

Additionally, regular policy evaluations conducted by governmental authorities are critical for effective SAF integration. Periodic assessments allow continuous improvement and adaptability, ensuring regulations remain aligned with technological advancements and market dynamics (European Commission, 2021). Establishing a mandated review process within Macedonian national aviation policy would ensure responsiveness to new challenges, effectively supporting sustained SAF integration by addressing emerging industry needs and continuously refining regulatory frameworks.

2.2.2 Collaboration with International Environmental Agencies

Collaboration with international environmental agencies is crucial for the successful integration and expansion of Sustainable Aviation Fuel (SAF) in Skopje. Effective partnerships allow access to global expertise, technical resources, and strategic funding opportunities, enhancing local capacity to achieve significant environmental goals (ICAO, 2021). Organizations such as the International Civil Aviation Organization (ICAO), United Nations Environment Programme (UNEP), and European Aviation Safety Agency (EASA) play essential roles in establishing international guidelines and best practices. Engaging these institutions ensures that local strategies align with international standards, facilitating smoother SAF adoption and operational harmonization.

ICAO provides significant guidance on sustainable aviation through its comprehensive frameworks, such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). This global program supports member states in reducing aviation emissions through various measures, including SAF integration and usage targets (ICAO, 2021). Active participation in CORSIA enables North Macedonia to access ICAO's extensive expertise, standardized methods for monitoring emissions, and technical assistance for SAF implementation. Such collaboration would facilitate Skopje's adherence to international aviation sustainability standards, thereby improving the city's environmental profile and fostering robust global partnerships.

Similarly, collaboration with UNEP can provide critical support through capacity-building

programs, technical assistance, and strategic funding for environmental initiatives. UNEP actively promotes cleaner fuels and energy transition programs worldwide, offering guidelines and technical frameworks essential for implementing sustainable aviation practices (UNEP, 2020). By partnering with UNEP, North Macedonia can leverage proven international approaches and methodologies for integrating SAF effectively. Such cooperation also facilitates access to international funding mechanisms aimed at environmental sustainability, thus significantly reducing initial financial barriers associated with SAF infrastructure development in Skopje.

Engagement with the European Aviation Safety Agency (EASA) ensures that local aviation operations adhere to rigorous safety and environmental standards required for SAF usage. EASA provides comprehensive regulatory oversight on fuel quality and operational standards, ensuring SAF's safe integration into commercial aviation (EASA, 2019). Collaborating closely with EASA would allow North Macedonia to quickly adopt these established standards, maintaining safety, reliability, and efficiency in SAF operations. EASA's regulatory frameworks serve as critical references, enabling Skopje to ensure compliance with European aviation norms, thereby enhancing operational interoperability within the broader European aviation market.

Furthermore, cooperation with international research consortia, such as the Clean Sky Joint Undertaking under the EU's Horizon Europe framework, significantly advances local innovation capacity. Clean Sky supports extensive research on sustainable aviation technologies, including alternative fuels, fuel efficiency, and emissions reduction (European Commission, 2021). Active participation in these research programs provides Macedonian institutions opportunities to gain vital knowledge and develop innovative technologies suitable for local implementation. Collaborative research not only fosters innovation but also accelerates technological readiness and market acceptance of SAF, ensuring long-term sustainability of aviation practices in Skopje.

International Renewable Energy Agency (IRENA) represents another valuable partner, providing crucial support for the renewable energy transition in aviation. IRENA's expertise in renewable energy policy, technological advancement, and investment strategies offers essential insights beneficial for SAF integration (IRENA, 2020). Through structured collaboration, Macedonian policymakers can access tailored policy recommendations,

financial strategies, and market analyses. Cooperation with IRENA ensures that local SAF production and utilization align effectively with broader renewable energy goals, thereby maximizing environmental and economic benefits associated with aviation sector sustainability in Skopje.

Collaborating with international financial institutions, such as the European Investment Bank (EIB), also provides vital funding opportunities for SAF-related infrastructure projects. EIB's substantial investments in sustainable transport infrastructure significantly facilitate large-scale projects aimed at reducing aviation sector emissions (EIB, 2020). North Macedonia could access EIB funding to support construction of SAF production facilities, enhancing production capacity and logistical infrastructure. Financial collaboration reduces initial investment risks, stimulates private-sector engagement, and provides economic incentives critical for the sustainable growth of SAF markets in Skopje.

The Global Environment Facility (GEF) is another essential partner providing strategic financial support and technical assistance for environmental sustainability projects globally. GEF-funded programs typically focus on reducing greenhouse gas emissions through innovation and sustainable practices (GEF, 2021). Through targeted partnerships with GEF, Skopje could implement ambitious SAF integration projects, supported by global financial and technical expertise. GEF funding mechanisms effectively leverage public-private partnerships, enhancing investment attractiveness, infrastructure scalability, and sustainability outcomes. Such partnerships ensure long-term viability of SAF projects, significantly contributing to regional environmental targets.

Collaboration with the World Resources Institute (WRI) further enhances local capacities through detailed technical analysis, policy support, and strategic planning. WRI offers comprehensive guidance on integrating renewable fuels within transport sectors, helping policymakers develop effective implementation strategies (WRI, 2021). Engaging WRI's expertise would provide North Macedonia critical insights into global best practices, robust data analytics, and effective policy frameworks. Such collaboration directly supports evidence-based policy decisions, helping Skopje develop well-structured, effective SAF integration plans that align with both national and international sustainability objectives.

Active engagement with Airports Council International (ACI) offers specialized insights into

airport-specific strategies for sustainable aviation fuel adoption. ACI provides technical manuals and operational guidelines aimed at enhancing airport-level environmental performance, including SAF infrastructure implementation (ACI, 2020). Collaboration with ACI would allow Skopje International Airport to adopt globally proven methods, enhancing operational efficiency and environmental performance. Through this partnership, airport management can effectively address logistical challenges associated with SAF storage, distribution, and blending, ensuring smooth integration and sustained airport operations aligned with international environmental standards.

The International Energy Agency (IEA) is instrumental in providing critical analysis, technological forecasts, and strategic policy recommendations for integrating sustainable energy solutions in transport sectors. Cooperation with IEA grants North Macedonia access to comprehensive market analyses, technical guidance, and best practices in sustainable energy policy implementation (IEA, 2021). Utilizing IEA's resources ensures informed decision-making, precise policy design, and effective market interventions. This collaboration significantly boosts local capacities, enabling policymakers to anticipate challenges, design resilient policies, and achieve accelerated, sustainable SAF integration within Skopje's aviation sector.

United Nations Framework Convention on Climate Change (UNFCCC) mechanisms offer North Macedonia access to global climate finance tools, facilitating strategic funding opportunities supporting SAF implementation. Programs such as the Green Climate Fund (GCF) provide financial support specifically aimed at sustainable energy transition projects within developing countries (UNFCCC, 2021). Skopje could strategically engage these financing instruments, significantly alleviating initial financial burdens associated with large-scale SAF adoption. Leveraging UNFCCC financial tools ensures that SAF initiatives effectively contribute to global climate commitments, thereby enhancing both environmental and diplomatic outcomes.

Collaboration with European Environment Agency (EEA) provides essential tools for comprehensive environmental monitoring, reporting, and data-driven policymaking. EEA offers rigorous methodologies and analytics required for accurately assessing SAF-related environmental outcomes (EEA, 2020). Engaging EEA's expertise allows Macedonian policymakers to effectively track SAF implementation progress, measure environmental

impacts, and improve transparency. Reliable monitoring ensures accountability, regulatory compliance, and continuous policy improvements, thereby supporting robust SAF integration within Skopje's aviation sector.

Strategic engagement with international NGOs such as Transport & Environment (T&E) enhances public awareness, advocacy, and stakeholder engagement in SAF projects. T&E's extensive expertise in policy advocacy, communication strategies, and public engagement helps build stakeholder support and public acceptance (T&E, 2021). Collaboration ensures effective public communication campaigns, stakeholder education, and enhanced public-private cooperation. Such partnerships strengthen social acceptance, market credibility, and long-term sustainability of SAF adoption efforts.

2.3 Strategic Roadmap for SAF Adoption in the Aviation Sector

2.3.1 Short-Term Strategies

Implementing Sustainable Aviation Fuel (SAF) requires clearly defined short-term strategies focused on immediate and achievable objectives. Initial steps involve setting incremental SAF blending targets, which are essential for establishing market predictability and fostering industry engagement. The European Commission strongly advocates gradual blending quotas, emphasizing that these quotas help build market stability, encouraging both producers and airlines to adopt sustainable fuels consistently (European Commission, 2018). Establishing modest yet mandatory blending percentages for the first two years can incentivize airlines to transition towards SAF without causing significant operational disruptions.

Financial incentives constitute another immediate priority for short-term strategy formulation. Providing initial subsidies to reduce SAF's price difference compared to conventional aviation fuel significantly influences airlines' willingness to integrate SAF into their operations (ATAG, 2020). Research indicates that direct subsidies during the introductory phase of sustainable fuel adoption greatly accelerate the industry's transition towards sustainability (ICAO, 2021). Government subsidies can lower financial barriers, making early adoption economically feasible, which stimulates initial demand and provides crucial market confidence to SAF producers seeking to expand production capacities

rapidly.

Streamlining regulatory frameworks in the short term also contributes significantly to effective SAF adoption. Short-term regulatory actions should involve the simplification of administrative processes related to licensing and approval of SAF production facilities (McKinsey & Company, 2021). Studies conducted in the European Union suggest that simplified procedures significantly reduce delays and administrative burdens, directly enhancing investment attractiveness (European Commission, 2021). Establishing a clear, simplified regulatory environment in the initial stages can speed up the establishment of local SAF production and distribution networks, supporting rapid market entry and efficient integration into the aviation sector.

Immediate investment in infrastructure, specifically storage, blending, and distribution facilities, represents another essential short-term strategy. Early infrastructure investment mitigates logistical challenges, significantly improving the supply chain's readiness for SAF integration (ICAO, 2021). Reports from Airports Council International (ACI) underline the importance of targeted infrastructure developments at major aviation hubs to facilitate early-stage SAF integration effectively (ACI, 2020). Thus, prioritizing such infrastructure investments ensures that necessary logistical capabilities are available promptly, enabling airlines to seamlessly incorporate SAF into their fuel procurement practices at Skopje International Airport.

Short-term training and education programs targeting aviation personnel also provide immediate strategic benefits. Quickly establishing training modules covering SAF handling, blending procedures, safety standards, and operational requirements significantly boosts stakeholders' technical readiness and compliance (ATAG, 2020). The European Aviation Safety Agency (EASA) emphasizes that early and targeted training ensures smooth operational integration, reducing safety risks associated with new fuel types (EASA, 2019). Implementing mandatory training courses for airline and airport personnel in the early adoption stages ensures operational efficiency, safety, and enhanced stakeholder support for SAF integration.

Transparent reporting and initial monitoring mechanisms represent another critical component of short-term strategic action. Implementing transparent reporting standards

from the beginning, based on proven models such as the European Union Emissions Trading System (EU ETS), encourages stakeholder accountability and provides essential data for future improvements (European Commission, 2021). Transparency during the initial implementation phase builds public and stakeholder confidence, clearly demonstrating the tangible environmental benefits of SAF usage. Regularly published data and reports help maintain stakeholder motivation, public support, and continuous alignment with environmental goals.

Creating initial public awareness campaigns highlighting SAF's environmental and economic benefits is essential for fostering early public acceptance. Successful case studies, such as those documented by the Air Transport Action Group, illustrate the importance of public education and communication in boosting early-stage acceptance and stakeholder engagement (ATAG, 2020). Short-term public outreach initiatives can involve digital media campaigns, educational workshops, and airport-level informational displays that clearly outline the advantages of adopting SAF. These strategies ensure broad public support and heightened consumer awareness, positively influencing market demand and stakeholder cooperation from the outset.

In the short-term context, the establishment of public-private partnerships (PPP) plays a vital role in rapidly scaling up SAF production capacity. International case studies from the Netherlands and Germany indicate PPP models efficiently distribute investment risks, leveraging private-sector expertise alongside governmental resources for rapid infrastructure development (ICAO, 2021). Early PPP establishment in Skopje could significantly accelerate local production capabilities, effectively addressing early market demand while laying robust foundations for future growth. These partnerships rapidly mobilize financial and technical resources, ensuring timely and efficient market entry.

Short-term financial support for targeted research and development initiatives also significantly advances early adoption efforts. Immediate research funding focused on alternative feedstocks, efficient production methods, and optimized logistics can address specific local challenges, enhancing local technical expertise and innovation (European Commission, 2019). Such short-term research initiatives provide rapid insights, enabling policymakers to quickly adapt and refine strategies for subsequent adoption phases. Initial targeted R&D investment thereby ensures continuous technical progress, maximizing early

adoption success rates and paving the way for sustained market growth.

Short-term strategic engagement with international bodies provides immediate technical, financial, and regulatory support essential for early SAF integration success. Establishing initial collaboration agreements with agencies such as ICAO, UNEP, and EASA ensures immediate access to international expertise and resources (ICAO, 2021; UNEP, 2020). Active short-term cooperation facilitates compliance with global standards, ensures immediate access to technical guidance, and significantly enhances the local SAF initiative's credibility. Early international collaboration thereby accelerates integration processes, supports stakeholder engagement, and enhances overall policy effectiveness.

Implementation of short-term government-supported guarantees for SAF procurement agreements is also strategically beneficial. Initial government backing for long-term purchase agreements between airlines and producers provides essential market stability and reduces early-stage investment risks (McKinsey & Company, 2021). Such immediate financial assurances encourage early adoption among airlines, ensuring stable demand and providing producers confidence to invest in expanding local production capacities. Immediate adoption of these financial instruments ensures rapid and effective market stabilization, accelerating overall adoption timelines and enhancing early-stage success rates.

Introducing targeted short-term economic incentives, such as reduced landing fees or airport charges for airlines adopting SAF, immediately improves adoption feasibility. Research underscores these financial mechanisms significantly influence airlines' initial adoption decisions, effectively combining economic incentives with environmental objectives (Norwegian Environment Agency, 2020). Quickly implementing these incentives at Skopje International Airport would directly encourage airlines to adopt SAF promptly, creating immediate market momentum. Early introduction of these financial incentives ensures immediate adoption progress, providing sustained motivation for airlines and producers alike.

Immediate integration of SAF goals within broader national sustainability frameworks ensures policy coherence and effective resource allocation. Aligning short-term aviation-specific SAF targets with North Macedonia's national climate and energy strategies

creates immediate cross-sectoral synergies (Ministry of Economy RNM, 2020). Short-term integration within national policy frameworks ensures governmental commitment, facilitates effective resource mobilization, and enhances stakeholder engagement across relevant sectors. Immediate strategic alignment ensures comprehensive governmental support, enhancing overall short-term adoption success and facilitating subsequent phases of SAF integration.

Short-term evaluation frameworks ensuring continuous monitoring of progress significantly enhance early-stage strategic effectiveness. Implementing immediate policy evaluation practices, informed by EU models, enables rapid identification of early challenges and necessary adjustments (European Commission, 2021). Short-term evaluation mechanisms ensure rapid feedback loops, continuous learning, and prompt corrective actions, supporting consistent improvements.

3 Research Methodology

This chapter outlines the research methodology employed to investigate the adoption and implementation of Sustainable Aviation Fuel (SAF) within the aviation sector. It details the overall research design, the qualitative methodological approach, the data collection and analysis processes, and the ethical considerations governing the study. By applying recognized qualitative research practices and ensuring methodological rigor, the study aims to provide a comprehensive understanding of stakeholders' perspectives and the factors influencing SAF adoption in Skopje's aviation context.

3.1 Research Design and Approach

The research adopts a **qualitative, exploratory design**, chosen to capture in-depth insights into perceptions, attitudes, and experiences of multiple stakeholders directly or indirectly involved in Skopje's aviation sector. Qualitative research is particularly suitable when the aim is to understand complex phenomena through the lens of participants' lived experiences (Creswell & Creswell, 2018). In this case, SAF adoption intersects with a variety of dimensions—economic, environmental, regulatory, and social—which benefit from rich, context-specific inquiry rather than purely quantitative measurements.

Within this exploratory framework, the **constructivist paradigm** underpins the study, assuming that knowledge is constructed through social interactions and participant interpretations. This paradigm aligns well with the research questions surrounding SAF adoption, as stakeholder viewpoints and experiences shape the collective understanding of both challenges and opportunities (Lincoln & Guba, 1985). The design emphasizes flexibility, allowing the researcher to adapt interview questions and probing techniques as new themes emerge, ensuring the data collection process remains responsive and comprehensive.

The **research aims** include:

- (1) examining stakeholder awareness and attitudes toward SAF,
- (2) identifying regulatory or policy barriers that influence SAF adoption, and
- (3) exploring strategies to encourage widespread SAF usage within the aviation sector in Skopje.

These objectives are best addressed through qualitative methods that emphasize the depth and richness of contextual insights, aligning with the emergent nature of SAF in global aviation.

3.2 Qualitative Research Methods

Qualitative methods offer the flexibility and depth needed to explore SAF adoption's nuanced implications. Given the diverse range of stakeholders, from policymakers and aviation industry leaders to community representatives, this study focuses on gathering narratives and experiences to form a holistic view (Bryman & Bell, 2015). Qualitative research allows for capturing underlying motivations, challenges, and contextual factors that may not be readily apparent in quantitative surveys.

3.2.1 Semi-Structured Interviews

Semi-structured interviews serve as the **primary data collection tool**, enabling a guided yet flexible conversation that explores key themes relevant to SAF adoption. This approach balances open-ended questions with a predefined framework, ensuring that

interviews remain focused on the research objectives (Kvale & Brinkmann, 2015). The semi-structured format facilitates comparability across interviews while allowing interviewees to discuss unique insights and elaborate on personal experiences. As documented in aviation sustainability research, semi-structured interviews effectively uncover barriers, drivers, and stakeholder viewpoints on emerging eco-innovations (ICAO, 2021).

An interview guide was developed covering critical areas, such as **awareness of SAF, economic feasibility, policy and regulatory frameworks, and community impact**. This guide ensured consistency, yet allowed interviewers to probe deeper when new or unexpected themes emerged. The semi-structured format thus provided the flexibility needed to capture both shared and divergent perspectives from different stakeholder groups involved in or impacted by aviation practices in Skopje.

3.2.2 Selection of Key Stakeholders

A **purposive sampling strategy** was adopted to identify stakeholders with relevant experience or influence in the context of SAF adoption (Patton, 2015). These stakeholders include:

1. **Policymakers and Regulatory Authorities:** Individuals from government agencies responsible for aviation oversight, environmental regulation, and energy policies.
2. **Aviation Industry Leaders:** Airline executives, airport managers, and aviation fuel suppliers whose operational decisions directly affect SAF usage.
3. **Environmental Experts:** Academics, researchers, and consultants specializing in sustainability, climate change, or air quality who can provide technical insights.
4. **Community Representatives:** Residents and local groups in Skopje, particularly those living near the airport, who might be directly affected by aviation emissions and noise.

This variety ensured that data collection encompassed a broad range of perspectives and experiences, enhancing the depth and credibility of the findings. Since SAF adoption intersects with multiple policy areas (European Commission, 2018), gaining input from all these stakeholder categories was essential for a holistic assessment.

3.3 Data Collection Process

The data collection process was structured to maintain consistency, maximize efficiency, and uphold ethical standards. It involved **developing interview questions**, **selecting and recruiting participants**, and **systematically documenting** all interviews through transcripts or recorded sessions for subsequent analysis (Creswell & Creswell, 2018).

3.3.1 Development of Interview Questions

Interview questions were carefully designed to align with the study's **research objectives** and to elicit detailed responses about SAF's feasibility, benefits, and challenges in Skopje. They addressed key areas:

- **Awareness and Understanding:** Interviewees' familiarity with SAF and perceived significance for Skopje's sustainability.
- **Environmental and Economic Implications:** Views on potential air quality improvements and cost considerations.
- **Policy and Regulatory Barriers:** Insights on existing legal frameworks, incentives, or obstacles to SAF implementation.
- **Community Impact:** Perceptions regarding local well-being, health, and quality of life.

Questions were **piloted** with a small subset of stakeholders for clarity and contextual relevance, and minor modifications were made to ensure accessible, comprehensible language. This pilot phase confirmed the appropriateness of the questions for eliciting in-depth qualitative data (Patton, 2015).

3.3.2 Selection and Recruitment of Interviewees

Interviewees were recruited using both **professional networks** and a **snowball sampling** method. Initial contacts within aviation authorities and environmental organizations offered referrals to additional participants matching the study's inclusion criteria (Bryman & Bell, 2015). Formal email invitations introduced the research objectives, confidentiality measures, and interview logistics. Participants who consented received follow-up communication to schedule interview dates and clarify any concerns.

During recruitment, efforts were made to ensure **balanced representation** across all stakeholder categories. This balanced approach aimed to capture a diversity of viewpoints, mitigating biases that might arise if only a single stakeholder group were involved. Recruitment continued until data saturation was achieved, meaning new interviews no longer generated novel themes or perspectives (Fusch & Ness, 2015).

3.4 Data Analysis Techniques

All interviews were recorded (with participant consent), transcribed verbatim, and systematically analyzed to identify recurring patterns, themes, and relationships. A **thematic analysis** approach was employed, following these steps:

1. **Familiarization:** Reading and re-reading transcripts to gain an overall sense of the data.
2. **Initial Coding:** Labeling significant phrases or concepts pertinent to SAF, such as “cost barriers,” “regulatory support,” or “community health.”
3. **Theme Development:** Grouping codes into broader categories or themes (e.g., “financial feasibility” or “environmental awareness”) capturing the essence of the coded segments.
4. **Reviewing Themes:** Refining and merging overlapping themes, verifying they accurately reflected the data.
5. **Defining and Naming Themes:** Providing precise labels and descriptions for each theme, ensuring clarity and coherence for interpretation (Braun & Clarke, 2006).

This method is especially suited for exploratory research, where themes emerge inductively from participant narratives (Patton, 2015). Triangulation was used by comparing findings across stakeholder groups, strengthening the analysis’s credibility (Lincoln & Guba, 1985). The researcher maintained a reflective journal throughout the coding process to document interpretive decisions and minimize subjectivity (Bryman & Bell, 2015).

4 Results

This chapter presents and describes the key findings from the research process, which was conducted with semi-structured interviews with diverse stakeholder groups. These groups included representatives from the public sector, aviation industry leaders, environmental experts, and community representatives. The main findings from the research are presented in five key themes: awareness and understanding of SAF, environmental benefits, economic feasibility, regulatory policy and needs, and community impact. Each theme includes direct positive and negative quotations from the conducted interviews to demonstrate how these key findings align with the research questions.

The collected empirical data from the interviews was analyzed thematically, where common themes or ideas were labeled with a star to reduce the excessive data. Moreover, the vague codes were discarded, and the relevant ones were highlighted and clearly presented, as they can play a significant role in further research and development projects in the field of Sustainable Aviation Fuels (SAF) adoption in Skopje and across the aviation sector worldwide.

Additionally, a summary of interviewees' key findings was incorporated at the end of this chapter (Table 2) to illustrate the main stakeholders' perspectives in relation to the discussed themes.

Awareness and Understanding of SAF

In this section, all five stakeholder groups were interviewed to explore their awareness and understanding when it comes to Sustainable Aviation Fuels (SAF) adoption and importance.

Most of the interviewees claimed that adopting SAF will positively affect human health and the environment. However, all interviewees agreed that raising awareness about SAF importance is necessary if we want to reduce local air pollution and improve the air quality in Skopje and the surrounding areas. Some of their statements were:

- The policymakers clarified their limited awareness of SAF, with one stating:

“While we are familiar with biofuels in general, SAF as a concept has not been a major focus during our general meetings related to the currently discussed topic.”

- Aviation Industry Leaders representatives demonstrated a deeper understanding of SAF, citing examples from European countries. One executive noted:

“SAF is the future of aviation, but without the infrastructure and policy support, it remains out of reach for us.”

- Environmental Experts were well-versed in SAF, emphasizing its potential to align with global climate goals, and during the open discussion, they all agreed that:

“We see SAF as green, pure, inspired by nature and science, and it can bring us back to our roots. However, raising awareness about its importance would probably speed up the process of airline stakeholders to accept Corporate Social Responsibility (CSR) as a core of their operations. Only then we might be able to create a climate-resilient pathway and improve the air quality in Skopje and the surrounding areas.

- Community representatives had a lack of information about SAF and their importance when it comes to improving the air quality, and stated that:

“We are well aware that the road transportation and factories are relying on fossil fuels, which is the main factor that our Skopje is one of the most polluted cities in the world. However, we strongly believe that shifting from conventional jet fuel to SAF in the aviation sector will make a big difference in terms of creating a more sustainable city. Public awareness of SAF's importance must be raised.”

Although these statements vary from each other, they all point out that community engagement and awareness campaigns could play a significant role in speeding up the process of SAF implementation and adoption.

Environmental Benefits

The environmental benefits section will explore and take a closer look at the interviewees' health and environmental concerns associated with aviation-related air pollution.

Moreover, the country's current position on the European SAF market will be revealed.

These are some of their quotations:

- A representative of the Civil Aviation Agency of North Macedonia, representing the policymakers, highlighted the recent SAF training organized by ECAC and held in Skopje:

“The meeting was a vital step forward in preparing North Macedonian airports to adopt the RefuelEU aviation initiative, which tends to become mandatory by 2025. It is a big step forward that will definitely reduce the country's environmental footprint from the aviation sector”.

- Aviation Industry Stakeholders unanimously agreed on SAF's environmental advantages. A policymaker remarked:

“If implemented effectively, SAF could significantly reduce our reliance on fossil fuels and improve air quality, which is critical for Skopje.”

- An environmental expert highlighted that SAF could reduce particulate matter emissions, stating:

“This would directly benefit communities living near Skopje International Airport by lowering respiratory illnesses.”

- Community representatives agreed upon the following:

“Without any doubt, this step will have a positive impact on improving the air quality in Skopje and the city's environmental condition over time.”

All respondents felt very optimistic in terms of SAF adoption and the potential to protect the public health of the citizens of Skopje. By following international best practices and tailoring solutions of SAF implementation, North Macedonia can enhance the sustainability of its aviation sector while protecting public health.

Economic Feasibility

In this section, the opinions among the participants were divided. Still, the focus remained on two points: the cost of SAF and the urgent need for regulatory reforms in terms of SAF integration in North Macedonia. Some of the participants stated that:

- The high cost of SAF emerged as a critical concern. An airline executive shared:

“SAF costs two to three times more than conventional jet fuel. Without subsidies, it is not commercially viable.”

- Policymakers recognized the economic challenge but suggested potential collaborations:

“We could explore partnerships with the EU to secure funding for SAF production facilities.”

- Following the round-robin approach during the discussion, one of the environmental experts noted that:

“SAF is probably the most credible and realistic way to reduce CO2 emissions to a larger extent and improve the air quality in Skopje. Therefore, joining the voluntary market of airport operators that adopted SAF to reduce emissions, despite the higher cost, needs to be taken into consideration”.

- Community representatives agreed that:

“The government must consider subsidizing the adoption of SAF at Skopje Airport. It would lead us towards creating a cleaner city and bluer skies while reducing CO2 emissions from the aviation sector and leaving the planet greener for the next generations”.

These divided responses indicate that aviation stakeholders and policymakers were looking at the bigger picture and expressed their concern in terms of SAF cost and a lack of sufficient regulatory support. Nevertheless, environmental experts and community representatives called for government-led initiatives to subsidize the transition to cleaner fuels.

Regulatory and Policy Needs

All respondents in the following section were unified regarding the questions discussed during the interview process. These are some of the quotations the participants used in the SAF regulatory and policy questionnaire part:

- One policymaker stated:

“The government must work on enforcing stronger regulatory frameworks and incentives, such as tax breaks or subsidies, to encourage SAF adoption.”

- Aviation stakeholders highlighted the revision of the Energy Taxation Directives (ETD), noting that:

“A mandatory government SAF tax exemption regulation will surely increase the usage of this renewable jet fuel in Europe, simultaneously reducing the environmental impact”.

- Environmental experts stressed the importance of aligning with international policies, with one noting:

“Following ICAO guidelines and EU standards could position North Macedonia as a regional leader in sustainable aviation.”

- Community representatives agreed that:

“Government subsidizing SAF implementation will have a positive impact on Skopje's air pollution problem and dealing with the climate change challenges in North Macedonia.”

The findings from the section are pointing out that regulatory gaps persist. Therefore, new policy measures are needed to ensure their strict compliance by all parties involved to avoid costly consequences. Additionally, international collaboration could make SAF economically viable, even for developing countries, such as North Macedonia.

Community Impact

In this section, respondents highlighted the economic challenges to SAF adoption and the importance of collaborating with international organizations. Furthermore, the need for cleaner air and reduced health risks associated with aviation emissions was emphasized.

- The interactive conversation during the interview led one of the policymakers to agree on one thing:

“Adopting SAF will create new job opportunities, which is good for the country's economy”.

- One of the aviation stakeholders noted that:

“The potential use of SAF at Skopje Airport will help in achieving three major goals. These are reducing aircraft noise, improving the local air quality in the city of Skopje and surrounding areas, and reducing the impact of aviation emissions on global climate change”.

- The environmental experts relied on the UN Sustainable Development Goals Agenda 2030. In regard to our discussion, the emphasis was placed on:

“Good health and wellbeing (SDG 3), Sustainable Cities and Communities (SDG11), and Climate Action (SDG 13) are the goals that must be highlighted if we want to make a difference and fulfill our dream, and that is to breathe a clean and fresh air in Skopje”.

- Community representatives expressed concerns about potential costs being passed on to passengers but acknowledged the environmental benefits. One resident mentioned:

“If SAF improves air quality and reduces noise pollution, it’s worth the investment. But we need transparency on how it will affect ticket prices.”

The respondents from the policymakers, aviation stakeholders, and environmental group highlighted the economic benefits and the country's economic growth from SAF adoption, simultaneously creating a healthier community. Conversely, the community representatives were more practical by putting the accent on the ticket cost increase, rather than thinking of the positive impact that SAF adoption could have for the environment and citizens of Skopje and surrounding areas.

The thematic analysis of these interviews identified three primary themes:

1. **Environmental Necessity:** SAF is seen as a critical solution for addressing air quality and emissions in Skopje.
2. **Economic and Policy Barriers:** The cost of SAF and the absence of supportive policies are significant obstacles.
3. **Collaborative Opportunities:** Stakeholders recognize the need for partnerships, both domestic and international, to facilitate SAF integration.

Table 2: Summary of Key Findings from Interviews

Theme	Key Insight	Example Quote
Environmental Benefits	SAF can reduce emissions and improve air quality.	“SAF is not just a cleaner alternative; it’s a necessity for sustainable aviation.”
Economic Feasibility	High costs remain the biggest barrier to SAF adoption.	“Without government support, the costs make SAF impractical for airlines.”
Policy & Regulatory Needs	Policies and incentives are crucial for SAF integration.	“We need frameworks that make SAF financially viable for stakeholders.”
Community Impact	Local communities see environmental potential but fear extra costs.	“We support SAF if it doesn’t disproportionately increase our living costs.”

To summarize the results, a spectrum of perspectives was revealed: with policymakers focusing on regulatory aspects, industry leaders highlighting economic and logistical challenges, environmental experts stressing on the urgency of adopting SAF to help Skopje fight air pollution, and community representatives emphasizing the local impact. This research provides a holistic understanding of SAF’s potential and the pathways for its adoption and improving air quality in Skopje.

5 Discussion

5.1 Analysis of Interview Findings

The analysis of interview findings revealed a nuanced understanding of Sustainable Aviation Fuels (SAF) among stakeholders, highlighting divergent perspectives on feasibility, cost, and long-term benefits. Policymakers tended to emphasize regulatory and institutional frameworks, reflecting their role in shaping aviation policies. In contrast, aviation industry representatives focused on economic and infrastructural aspects, citing both immediate and projected costs as significant considerations. Environmental experts consistently underscored the urgency of transitioning to SAF as part of broader climate action and local air quality improvement. Community representatives expressed mixed levels of familiarity, with some recognizing SAF's potential benefits and others remaining unsure of its direct impact. These diverse viewpoints underscore the importance of multi-stakeholder collaboration in advancing SAF integration.

Most policymakers interviewed acknowledged a growing awareness of SAF at the governmental level, though they cited limited comprehensive strategies for rapid adoption. They reported preliminary discussions that hinge on aligning with international directives, especially those set forth by the European Union (European Commission, 2018). Their emphasis on inter-ministerial coordination and cross-sector collaboration underlined the complexity of incorporating SAF into a traditionally cost-sensitive aviation sector. Beyond policy discussions, policymakers identified the need for targeted research and stronger stakeholder engagement to ensure effective policy formation that resonates with both industry participants and local communities.

Aviation industry leaders recognized SAF as a potentially transformative step toward reducing carbon footprints. However, they highlighted the current lack of established local supply chains and infrastructure, which complicates procurement and distribution. They expressed concerns about limited incentives to offset higher SAF production costs, underscoring the financial risks involved when transitioning from conventional aviation fuel to more expensive, albeit sustainable, alternatives. Many industry participants called for better alignment between governmental ambitions and industry realities, suggesting tailored subsidies, tax benefits, or clear blending mandates to make SAF more

commercially viable in Skopje.

Environmental experts consistently emphasized the environmental urgency of adopting SAF to mitigate both local air pollution and global climate impacts. They pointed out that even modest SAF blending rates can significantly reduce particulate matter, nitrogen oxides, and greenhouse gas emissions (ICAO, 2021). Many experts advocated for robust research initiatives aimed at exploring region-specific feedstocks, citing the potential for circular economy approaches in North Macedonia. They highlighted how successful implementation of SAF in Skopje would align with international climate goals, such as the Paris Agreement, and improve overall regional air quality, benefiting local residents.

Community representatives exhibited varied levels of awareness regarding SAF. Some individuals closely monitored environmental developments at the airport, voicing support for any measures that could improve local air quality and reduce noise pollution. Others lacked specific knowledge of SAF's potential, linking the topic more broadly to environmental and quality-of-life concerns in the city. Despite these varying awareness levels, most community voices expressed optimism that transitioning toward greener fuels could positively impact public health and local ecosystems, providing it did not significantly increase travel costs or tax burdens.

From a methodological standpoint, the interviews confirmed that semi-structured conversations allowed stakeholders to elaborate on context-specific insights. This structure proved particularly valuable in uncovering nuanced perspectives about SAF's feasibility, spanning policy constraints, financial incentives, and societal benefits. The approach ensured that each interviewee addressed core themes, while follow-up probes explored underlying motivations and concerns. Data saturation occurred once consistent themes, such as cost, regulatory support, and sustainability awareness, recurred across stakeholder groups, reinforcing the rigor of the qualitative design.

Interview data also illuminated areas where stakeholder views converged, notably the recognition of Skopje's chronic air quality challenges. Nearly all participants agreed that adopting cleaner fuels—particularly in sectors generating significant emissions—could yield health and environmental advantages. This consensus offered a strong foundation for policy discourse, given the shared acknowledgment of aviation's contribution to local air

pollution and the potential of SAF to address it. However, differing opinions emerged about the scale and speed of SAF implementation feasible under current financial and policy constraints.

Stakeholders frequently referenced the broader sustainability context, linking SAF adoption to overarching national and international targets. Policymakers cited ongoing efforts to harmonize with EU directives, particularly regarding renewable energy and decarbonization targets. Aviation representatives mentioned upcoming global emissions-reduction milestones set by organizations like ICAO. Environmental experts framed SAF as part of a holistic approach, complementing improvements in airport operations and ground transportation. This wide-ranging perspective underscores how SAF adoption resonates beyond aviation alone, tying into large-scale sustainable development agendas.

Despite the enthusiasm for SAF, many interviewees noted that successful implementation requires robust policy frameworks. The notion of “policy certainty” emerged repeatedly, with participants arguing that stable, clearly defined regulations reduce the perceived risk for both investors and aviation companies. They suggested that without reliable governmental commitments—such as blending mandates, financial incentives, or streamlined permitting—industry stakeholders would remain hesitant to invest substantially in SAF. This underscores the interplay between interview findings and policy-making processes, highlighting the potential alignment of multiple interests through strong legislative action.

Several participants drew attention to potential partnerships between government bodies, private entities, and international organizations. These collaborations could streamline SAF supply chain development, research activities, and capacity-building programs. Interviewees observed that successful SAF implementation in other regions often stems from multi-stakeholder coalitions leveraging technical expertise, financial backing, and supportive regulations (Norwegian Environment Agency, 2020). In Skopje, similar alliances could help overcome infrastructural bottlenecks, mitigate cost barriers, and share risks associated with an emerging market for sustainable fuels.

A notable theme was the role of public awareness and outreach in shaping SAF’s future in Skopje. Policymakers and environmental experts stressed that transparent, consistent

communication about SAF's environmental and health benefits can promote community acceptance and consumer support. In turn, community backing could motivate both airlines and local governments to prioritize SAF, creating a feedback loop that reinforces environmental and social outcomes. However, some interviewees warned that insufficient or misleading information might cause confusion or skepticism, underscoring the need for clear, fact-based messaging.

In terms of limitations, the interviews also highlighted data gaps, particularly regarding local feedstock availability for SAF production. While some stakeholders perceived potential in locally sourced agricultural residues or waste-to-fuel technologies, definitive assessments of feedstock volumes and processing feasibility remain limited. Closing these data gaps would be crucial for long-term planning, guiding investment decisions, and ensuring that SAF initiatives align with broader sustainability considerations such as land use, community acceptance, and logistical viability (European Commission, 2019).

The interview findings underscore that while enthusiasm for SAF is growing, practical hurdles persist. Economic considerations—encompassing higher fuel costs, the need for subsidies, and uncertain returns on infrastructure investments—remain at the forefront of discussion. Regulatory clarity, in alignment with international benchmarks, also appears pivotal for sustaining momentum. Stakeholders consistently underlined the value of a phased approach, starting with achievable blending quotas and gradually expanding as technology matures and costs decline, reflecting how incremental strategies can mitigate risks and catalyze progress.

5.2 Advantages of SAF Adoption in Skopje

Sustainable Aviation Fuel (SAF) adoption in Skopje presents numerous advantages, reflecting its potential to balance economic development, environmental health, and social welfare. Interviews with policymakers highlight expectations for SAF to reduce aviation-related emissions, improve local air quality, and position Skopje as a regional leader in green aviation. Environmental experts agree, emphasizing SAF's role in mitigating carbon footprints and lowering particulate matter in areas surrounding the airport. Aviation stakeholders see the prospect of improved reputation and market competitiveness, recognizing that consumers and regulators alike increasingly demand clean-energy

solutions.

A key benefit of SAF integration lies in carbon emission reductions, as SAF can potentially curb net greenhouse gas emissions by up to 80 % over its lifecycle compared to conventional jet fuel (ICAO, 2021). This aligns well with broader European decarbonization goals, aiding North Macedonia in meeting international commitments under climate agreements. By positioning Skopje as an early adopter, stakeholders argue that the city can capitalize on funding opportunities and partnerships focused on sustainable aviation initiatives. Such advantages also extend to reputational gains, helping Skopje distinguish itself as environmentally forward-thinking.

From an economic perspective, SAF can stimulate local industries involved in feedstock production, refining, and distribution. The creation of specialized processing facilities and job opportunities in the green energy sector can catalyze economic growth (European Commission, 2019). Interviewees highlight that if local agricultural residues or waste products are utilized, farmers and waste-management enterprises could experience secondary benefits. This synergy offers a diversification strategy for North Macedonia's economy, especially if supported by consistent government policies and international funding mechanisms dedicated to sustainable energy transitions.

Public health emerges as another significant advantage, especially concerning air quality improvements. Conventional aviation fuels contribute to harmful emissions, including particulates and nitrogen oxides, which exacerbate respiratory issues and degrade urban living conditions (ATAG, 2020). SAF, derived from cleaner combustion processes, emits fewer pollutants, potentially alleviating health risks for residents near airports. Such improvements in public health can translate into reduced healthcare costs, increased workforce productivity, and enhanced overall quality of life, thus reinforcing the socioeconomic rationale for SAF adoption in Skopje.

At the community level, local stakeholder engagement suggests that SAF adoption could foster a sense of collective responsibility and pride. Community representatives who participated in the interviews acknowledged that environmental initiatives, if communicated effectively, can galvanize public support. Emphasizing the direct benefits of reduced noise, cleaner air, and healthier living conditions can bolster civic pride, leading to stronger

community backing. Such support is essential for sustaining policy initiatives over time, as grassroots endorsement often proves decisive in ensuring the longevity and success of environmental programs.

Another advantage lies in regulatory alignment with EU directives, which increasingly incentivize cleaner fuels in transportation sectors. Adopting SAF early can place Skopje at the forefront of regional compliance, potentially easing future transitions as regulations become more stringent (European Commission, 2021). Policymakers highlight that proactive measures taken now can mitigate future burdens related to carbon taxation or penalties associated with non-compliance. Additionally, aligning with EU standards can attract external funding, given the union's emphasis on supporting members and neighbors in achieving sustainability milestones.

The aviation industry stands to benefit from improved consumer perception linked to sustainability initiatives. Airlines operating out of Skopje that commit to SAF usage could market themselves as eco-conscious, appealing to passengers increasingly concerned about their carbon footprint. Interview data confirm that a segment of consumers is willing to pay a premium for flights that demonstrate tangible commitments to environmental stewardship. These market-driven advantages, combined with potential brand differentiation, create a strong argument for early SAF adoption by carriers seeking a competitive edge.

Infrastructure modernization forms part of the broader advantages associated with SAF implementation. Upgrading airport facilities, storage systems, and fueling logistics not only accommodates SAF but can also enhance overall operational efficiency. Investments in more advanced fuel-handling procedures and technology can lead to reduced spillage risks, improved fuel-quality monitoring, and better synergy with ground-support equipment (Norwegian Environment Agency, 2020). These ancillary improvements reinforce the argument that SAF adoption transcends environmental gains and extends to operational resilience and cost savings in the long term.

On an international collaboration level, early adoption of SAF could strengthen North Macedonia's ties with organizations such as ICAO and the European Aviation Safety Agency (EASA). These collaborations allow knowledge transfer, technical assistance, and

joint research opportunities focusing on feedstock innovation or advanced refining technologies (ICAO, 2021). By networking with international bodies, Skopje can remain updated on evolving standards and best practices, ensuring that its SAF initiatives align with cutting-edge developments in global aviation sustainability.

Regional leadership also emerges as a notable advantage. Interviewees suggest that if Skopje successfully integrates SAF, it could inspire neighboring countries to adopt similar measures, creating a ripple effect across the Western Balkans. This leadership role might accelerate the formation of cross-border supply chains, reducing costs and sharing risks associated with emerging technologies. By spearheading such efforts, Skopje could solidify its reputation as an environmental pioneer in southeastern Europe, attracting further investment in sustainable transport and related industries.

Furthermore, resilience to fossil fuel volatility stands out as an important advantage. Traditional jet fuel prices often fluctuate based on geopolitical events and global market conditions, potentially disrupting airline operations and ticket pricing. SAF, especially if sourced locally through diverse feedstocks, can offer more stable supply chains less vulnerable to external shocks (McKinsey & Company, 2021). While SAF may currently be costlier, strategic investments, scaling, and technology improvements could lead to greater price stability, thereby enhancing the aviation sector's resilience in the long run.

Investing in SAF underscores a commitment to innovation within North Macedonia's energy and transport sectors. By supporting pilot projects, research and development, and advanced feedstock exploration, the country could nurture a high-skill workforce specializing in renewable energy technologies. Such initiatives might draw professionals, researchers, and entrepreneurs keen to work on pioneering sustainability solutions, contributing to a broader innovation ecosystem. The positive spillover of this intellectual capital could extend to other industries, amplifying the transformative potential of SAF initiatives in Skopje.

Societal co-benefits also emerge when viewing SAF adoption through the lens of sustainable development goals (SDGs). By reducing carbon emissions and improving air quality, SAF directly contributes to climate action (SDG 13) and good health and well-being (SDG 3) (United Nations, 2015). It further supports responsible consumption and

production (SDG 12) if carefully managed with sustainable feedstock sourcing. The multi-faceted alignment with SDGs enhances SAF's attractiveness for potential investors, international donors, and community stakeholders, who increasingly prioritize cross-cutting environmental and social impacts.

Market differentiations, such as specialized "green routes," could emerge as SAF usage in Skopje expands. Airlines might designate certain flights as being powered by a higher proportion of sustainable fuel, tapping into evolving consumer preferences. Environmental experts believe this could become a defining feature of the local tourism market, as travelers consciously select eco-friendly travel options. Coupled with improved air quality and environmental awareness, these developments could reshape Skopje's aviation identity, making sustainability a central theme in the city's growth narrative.

5.3 Challenges to SAF Implementation

Despite the promising outlook for SAF in Skopje, significant challenges remain that hinder large-scale implementation. Interviews highlighted hurdles in production, regulatory frameworks, and public awareness, each demanding targeted strategies for resolution. Industry leaders pointed to economic obstacles such as elevated feedstock and refining costs, while policymakers cited complications around harmonizing local regulations with international guidelines. These challenges underscore that while SAF's advantages are compelling, systematic and collaborative efforts are necessary to move from pilot projects to mainstream adoption.

Stakeholders frequently emphasized that the production costs of SAF are currently higher than those of conventional jet fuel. This cost differential poses a fundamental barrier for airlines operating on slim profit margins. Without clear subsidies, tax reliefs, or carbon pricing mechanisms that reflect the true externalities of fossil fuels, many carriers hesitate to invest in SAF. Consequently, production volumes remain limited, perpetuating higher prices and creating a "chicken-and-egg" scenario that stalls widespread adoption (McKinsey & Company, 2021).

Regulatory barriers represent another critical challenge. Interviewees noted that North Macedonia, though aspiring to align with EU standards, faces legislative gaps preventing efficient adoption of SAF. For instance, the absence of mandatory blending targets or

structured incentives can dampen investor interest. Policymakers acknowledged that drafting new laws or amending existing ones to explicitly cover SAF can be time-consuming. Additionally, certain local regulations may inadvertently complicate licensing for potential SAF producers, increasing administrative burdens and project lead times.

Public perception emerged as a nuanced obstacle. While some community members and passengers exhibit curiosity about cleaner aviation fuels, others remain skeptical or uninformed. Interview respondents cited instances where incomplete or misleading information fosters mistrust, complicating consensus-building. Aviation experts stressed that consumer endorsement of SAF usage, especially if it leads to marginal ticket price increases, depends on transparent communication about health and environmental benefits. Failure to effectively educate the public risks undermining the market demand necessary to sustain SAF initiatives in Skopje.

Complexities around feedstock availability add further layers of difficulty. North Macedonia's capacity to produce large volumes of feedstock—such as used cooking oil, agricultural residues, or algae—remains uncertain. Stakeholders lack comprehensive data on potential production scales, logistical feasibility, and economic viability. Environmental experts worry about unintended land use changes if feedstock cultivation displaces food crops or natural habitats (European Commission, 2019). Overcoming this challenge demands detailed research, strategic planning, and rigorous sustainability criteria for feedstock sourcing.

Infrastructural inadequacies also present obstacles to SAF's market entry. From distribution pipelines to specialized storage facilities, Skopje International Airport may require significant upgrades to handle SAF safely and efficiently. Airlines noted that ground support procedures for fueling with SAF differ slightly from conventional processes, necessitating staff training and, in some cases, specialized equipment. The lack of existing infrastructure dissuades potential investors, who often prefer markets with well-established logistical support for alternative fuels (Norwegian Environment Agency, 2020).

Aviation industry interviewees lamented the lack of consistent policy signals from the national government. Shifting political landscapes and budgetary constraints can delay or dilute sustainability initiatives, frustrating long-term planning. Without stable policies

guaranteeing partial or full support for SAF adoption, industry leaders struggle to justify the capital investments necessary for large-scale transitions. This reality underscores the vulnerability of sustainability programs to political cycles, emphasizing the need for bipartisan or cross-ministerial consensus on environmental priorities.

The initial cost burden of adopting SAF can also lead to concerns over competitiveness. Airlines operating in price-sensitive markets worry that any additional expenses passed on to consumers may reduce passenger numbers, especially if neighboring airports offer cheaper flights fueled by conventional jet fuel. This dynamic can discourage pioneering efforts, as carriers fear losing market share unless neighboring regions adopt similar sustainability measures. Some policymakers suggested regional coordination to ensure a level playing field, but implementing such cooperation requires extensive diplomatic and economic negotiations.

Technological uncertainties also hinder definitive planning for SAF. Although several production methods (such as Fischer–Tropsch synthesis, HEFA, or alcohol-to-jet) show promise, not all are commercially mature or scaled for mass adoption (ICAO, 2021). Industry stakeholders express caution about investing heavily in one technology only to see another emerge as superior. This uncertainty extends to feedstock breakthroughs, such as advanced algae cultivation, that remain largely experimental. Such fluidity suggests a watchful, adaptive approach where partial commitments to multiple pathways may be more prudent.

Potential logistical constraints around feedstock importation or distribution networks pose further complications. If local supplies prove insufficient, Skopje may rely on foreign producers, subjecting SAF availability and pricing to international market dynamics. This reliance challenges policy goals aimed at fostering local energy independence. Additionally, cross-border logistical chains introduce regulatory complexity, including customs procedures, transport safety standards, and potential trade barriers. Interviewees agreed that thorough feasibility studies are imperative before finalizing any large-scale SAF deployment strategy.

Community interviews hinted at equity concerns, particularly if SAF adoption raises ticket prices or tax burdens. Some residents fear they may bear disproportionate costs for an

initiative that primarily benefits frequent travelers or businesses. To address these worries, policymakers must ensure transparent financial structures, where government subsidies or progressive taxation do not unfairly impact lower-income populations. Balancing environmental benefits with social equity is essential for garnering public support and preempting resistance to aviation-related sustainability measures.

Several experts pointed out that bridging knowledge gaps could mitigate many challenges. Detailed economic modeling, pilot programs, and feedstock feasibility assessments can offer clarity on costs, operational complexities, and long-term viability (Bryman & Bell, 2015). Collaboration with academic institutions or international research bodies can accelerate this knowledge-building process. Without credible and localized data, both policymakers and industry representatives operate on assumptions, potentially leading to ineffective or misaligned strategies that squander resources.

Finding effective financing mechanisms remains a critical concern. While some stakeholders champion government-led subsidies, others suggest market-based approaches such as carbon taxes or offset programs that place a tangible price on emissions. International grants or green bonds might offer additional avenues for capital, though securing these funds often requires detailed proposals and compliance with strict guidelines (European Commission, 2021). The viability of any financing model depends on consistent policy frameworks, political will, and stakeholder consensus, reiterating the interconnected nature of SAF challenges.

5.3.1 Production Costs

Production costs emerged as a prominent theme among interviewees, reflecting a widespread concern that SAF remains more expensive than conventional jet fuel. This cost differential stems from factors such as feedstock price fluctuations, refining complexities, and limited economies of scale (McKinsey & Company, 2021). Airlines operating at narrow profit margins often struggle to justify higher fuel bills, while governments face budgetary constraints limiting their capacity to subsidize greener alternatives. Such market realities slow SAF adoption, even as stakeholders acknowledge its environmental advantages.

Industry representatives highlighted the “early adopter penalty,” wherein pioneering

airlines shoulder higher costs to support emergent technologies and supply chains. They underscored that, without predictable policies or supportive incentives, these companies risk financial disadvantages relative to competitors using cheaper fossil-based fuels. In some cases, carriers may pass costs onto passengers, potentially reducing passenger volumes and eroding competitiveness in price-sensitive markets. This dynamic hampers the consistent demand required for large-scale SAF production facilities.

Policymakers emphasized that bridging the cost gap often requires a mixed policy toolbox, including subsidies, tax reliefs, and emissions trading schemes (European Commission, 2021). However, implementing such measures can be politically challenging, particularly if public funds are diverted from other social or economic programs. Interviewees suggested that well-crafted incentives, phased to decline as SAF production scales and costs drop, may strike a balance between encouraging adoption and mitigating indefinite government spending. This approach aligns with international examples where partial state support gradually tapers off.

Feedstock limitations also drive production costs upward. Sourcing sustainable materials in sufficient volumes may involve importing from distant regions, adding transportation expenses. Even domestic feedstocks like agricultural residues can require advanced pretreatment, specialized logistics, and capital-intensive conversion processes (ICAO, 2021). The combination of these factors inflates per-liter SAF prices, diminishing affordability for airlines and, by extension, their customers. Addressing feedstock scarcity and expensive refining steps is essential to achieving competitive pricing.

Aviation experts pointed out that scaling up SAF facilities could eventually unlock cost benefits through improved supply chain integration and process efficiencies. Larger production plants can negotiate better feedstock prices, spread fixed operational costs, and invest in research to refine conversion technologies. Over time, these factors can lower unit costs, narrowing or eliminating the price gap with conventional fuel.

Nonetheless, achieving scalability requires initial high capital outlays and assurances of stable demand from airlines, forming a cycle that demands robust risk-sharing mechanisms.

One potential avenue to address cost concerns involves public-private partnerships (PPP),

leveraging governmental support alongside private-sector expertise. By sharing financial burdens, PPPs can de-risk investments in SAF production infrastructure, accelerate technology validation, and cultivate specialized industry clusters (Norwegian Environment Agency, 2020). Policymakers interviewed proposed offering land concessions, tax incentives, or guaranteed purchase agreements to encourage private investors to build local SAF plants. However, the success of such models depends on transparent governance, clear contractual terms, and reliable feedstock availability.

Interviews also revealed an appetite for innovative financing strategies, such as green bonds or carbon offsets, to cover a portion of SAF's premium. Airlines that commit to purchasing SAF could issue sustainability-linked financing products, tying interest rates to emission-reduction targets. Though these structures introduce added complexity, they can mobilize environmentally conscious investors seeking tangible climate impacts (ICAO, 2021). By coupling these financial instruments with regulatory support, Skopje could create a more favorable environment for cost-competitive SAF production.

Some interviewees questioned whether short-term cost burdens might be outweighed by long-term social and health benefits. For instance, reducing air pollution through SAF can potentially lower healthcare expenses, boost tourism, and enhance community well-being—factors with monetary value often overlooked in traditional cost analyses (ATAG, 2020). This broader perspective suggests that a purely market-based evaluation of SAF's cost-effectiveness may undervalue its cumulative socio-environmental dividends. Encouraging decision-makers to adopt a comprehensive cost-benefit lens could legitimize public investments in SAF infrastructure and bridging funds.

Airlines also explored the concept of cost-sharing with passengers, especially for those who opt into “green flights.” Some carriers experiment with voluntary surcharges enabling travelers to fund SAF purchases, making them active stakeholders in emission reductions. While this approach may remain limited by consumer willingness to pay, it reflects growing public awareness of carbon footprints (European Commission, 2019). If carefully communicated, a cost-sharing model can forge a cooperative relationship between airlines and eco-conscious customers, channeling resources into SAF adoption without overburdening operational budgets.

At the policy level, adjusting fossil fuel subsidies or introducing levies on traditional jet fuel might realign market prices to reflect actual environmental costs. By narrowing the gap between SAF and conventional fuel, such measures effectively internalize pollution externalities (ICAO, 2021). However, policymakers acknowledge the social and political sensitivity of increasing fuel taxes, particularly if it raises ticket prices. Careful design and gradual implementation can mitigate backlash, ensuring that revenues from these levies funnel directly into SAF research, infrastructure, or consumer relief programs.

Community members expressed mixed reactions to passing SAF costs to consumers, reflecting divergent socioeconomic realities. While some view incremental fare increases as justifiable for climate and health benefits, others warn that higher ticket prices could exacerbate inequalities, limiting air travel to wealthier segments. This tension highlights the importance of equitably distributing financial burdens among passengers, the aviation sector, and the government, ensuring that crucial environmental measures do not disproportionately affect certain populations.

Addressing logistical efficiencies is another way to tackle production costs. Setting up integrated “feedstock-to-fuel” chains might reduce transportation expenses and intermediate processing steps, ultimately lowering SAF prices (Norwegian Environment Agency, 2020). Partnerships with local suppliers, port authorities, and rail networks can optimize the movement of raw materials, particularly if feedstocks are bulky or perishable. By treating cost reduction as a supply chain challenge, Skopje’s aviation stakeholders can uncover operational synergies that help offset SAF’s initial premium.

Stakeholders generally agreed that even if SAF remains more expensive in the short term, incremental adoption could build the momentum needed for future cost reductions. Early efforts create market signals encouraging investment, infrastructure development, and policy innovation. Over time, improved technologies, economies of scale, and rising carbon costs for fossil fuels can close the price gap (European Commission, 2021). Proponents believe that those who start early may gain competitive advantages, shaping the trajectory of green aviation in the region.

5.3.2 Regulatory Barriers

Regulatory barriers emerged prominently in stakeholder discussions on SAF, encompassing the complexity of aligning national laws with international directives, the absence of clear mandates, and administrative bottlenecks. Since North Macedonia is not yet an EU member, bridging local regulations with EU norms can be an arduous process. Policymakers underscored their intent to harmonize with European frameworks, but progress is hindered by limited institutional capacity and competing legislative priorities.

A recurrent topic was the lack of mandatory SAF blending requirements, a tool used in some countries to stimulate demand. Without explicit targets, airlines may not prioritize SAF, especially if cost considerations dominate. Aviation industry stakeholders suggested that legislating phased mandates—such as a rising percentage of SAF over time—could provide long-term certainty and encourage investment in production infrastructure (European Commission, 2021). However, policymakers hesitated to endorse mandates without first ensuring feedstock availability and cost feasibility.

Administrative complexity compounds the problem. Prospective SAF producers encounter extensive licensing requirements, often spread across multiple government agencies with limited inter-coordination. Interviewees described a labyrinth of permit applications, environmental impact assessments, and land-use approvals that inflate costs and prolong timelines. Policymakers acknowledged these red tape issues, suggesting that a centralized “one-stop shop” for alternative fuel projects might streamline the process. However, implementing such structural reforms requires high-level political backing.

Uncertainty about quality standards also poses a regulatory hurdle. While international bodies like ASTM International provide specifications for SAF blends, local authorities in Skopje may lack the technical capacity to verify compliance (ICAO, 2021). This gap undermines consumer and airline confidence, as stakeholders question fuel quality, aircraft safety, and warranty implications. Establishing robust certification bodies and training inspectors to handle SAF’s specificities could reduce these worries, but such initiatives demand resources and expertise not yet fully available.

Other interviewees mentioned policy inconsistencies across ministries, with energy departments sometimes promoting biofuel incentives that do not fully account for aviation’s

technical parameters. This siloed approach leads to fragmented regulations, where some fuels qualify for subsidies under general bioenergy schemes but fail to meet aviation-grade requirements. Harmonizing bioenergy standards to explicitly include aviation fuels could simplify compliance, encourage producers, and clarify eligibility for financial incentives, fostering a more coherent policy landscape.

Regulatory caution also arises from concerns about feedstock sustainability. Authorities may hesitate to encourage large-scale SAF production if it risks deforestation, water resource depletion, or food security. While robust criteria exist internationally, their transposition into Macedonian law is incomplete (European Commission, 2019). Policymakers worry about accountability and enforcement capacities, noting that any environmental abuses under SAF production could prompt public backlash and undermine trust in greener aviation initiatives.

Limited integration of international guidelines also complicates Skopje's ability to align with global best practices. For instance, the EU's Renewable Energy Directive II and ICAO's CORSIA program outline frameworks that can inform national policies (ICAO, 2021). Yet, without a direct obligation to comply, progress may stall due to competing legislative agendas. Interviewees suggested that actively joining voluntary initiatives or pre-emptively adopting EU directives could accelerate standardization, reduce confusion, and position Skopje as a proactive actor in sustainable aviation.

A critical missing piece is the legal definition of SAF within national aviation laws. Standardizing language around feedstock types, blending ratios, and sustainability credentials is necessary for consistent enforcement and policy drafting. Policymakers admitted that crafting such definitions requires multidisciplinary input from environmental scientists, economists, and aviation experts. Until these definitions are codified, confusion persists about what qualifies as SAF, stifling broad-based adoption.

Stakeholders also noted that long legislative timelines clash with the immediate need to address climate change and air quality. Drafting, debating, and passing new laws or amendments can span multiple years, while industry transitions demand more agile responses. This mismatch fuels frustration among innovators eager to invest in SAF production, only to be hindered by protracted political or bureaucratic processes. Some

experts advocated for interim executive orders or pilot initiatives while formal regulations remain under development, providing short-term clarity without sacrificing legislative rigor.

Transparency in tracking and reporting SAF usage is another regulatory gap. Without standardized metrics or mandatory disclosure, airlines that utilize SAF cannot showcase their efforts credibly, and policymakers cannot measure progress. Implementing robust monitoring systems, akin to those employed by the EU ETS, can instill confidence that claims of reduced emissions or improved air quality are substantiated (European Commission, 2021). Such systems also enable data-driven policymaking, guiding adjustments in incentives or blending mandates based on real-world performance.

Confusion over taxation policies further hinders SAF adoption. In some jurisdictions, sustainable aviation fuels enjoy tax exemptions or reduced excise duties, leveling the playing field with cheaper fossil fuels (Norwegian Environment Agency, 2020). Interviewees in Skopje indicated that tax codes remain outdated, failing to differentiate between conventional and sustainable fuels. Revising tax laws to incorporate a partial or full exemption for SAF could significantly reduce cost barriers, but progress lags due to fiscal concerns and administrative inertia.

The interplay between domestic interests and global aviation regulations adds another dimension of complexity. Airlines operating international routes must comply with ICAO guidelines and might adopt SAF if mandated abroad, even if local rules are less stringent. This incongruity can place local carriers at a disadvantage or create regulatory loopholes. Experts recommend cooperation with regional aviation authorities to harmonize standards, ensuring consistent mandates across key markets and avoiding policy patchworks that undermine compliance and competitiveness.

Interview participants argued that political will is ultimately decisive in surmounting regulatory barriers. While technical expertise and legislative mechanisms exist, political leaders must champion SAF adoption as an environmental and economic priority. Such advocacy often hinges on broader public awareness and media attention, placing additional emphasis on the role of civil society in demanding stricter regulations and accountability. Without strong, visible political support, even well-designed policies risk stalling amid competing interests.

5.3.3 Public Perception

Public perception profoundly influences the success of SAF initiatives, as local communities and travelers ultimately determine the social license for adopting new technologies. Interviews revealed that while many residents near Skopje International Airport are anxious about air quality and noise, they remain largely unaware of how SAF addresses these issues. This knowledge gap can diminish enthusiasm or create skepticism, particularly if any cost repercussions are passed on to end-users.

Some policymakers and community members reported misconceptions about SAF, conflating it with biofuels used in ground transportation or doubting its real environmental benefits. A few believed that SAF might be a superficial fix, overshadowing deeper reforms needed in airport operations. This skepticism underlines the importance of accurate, accessible information detailing SAF's life cycle impacts and the scientific consensus behind its viability (ICAO, 2021). Successful public engagement strategies will likely hinge on clarifying such technical distinctions.

Marketing and communication emerged as pivotal elements in shaping public views. Interviewees suggested that airlines and airport authorities should actively highlight SAF usage and the associated pollution reductions. Clear branding, in-flight announcements, and digital content explaining how SAF works could foster positive impressions. However, these efforts must avoid “greenwashing,” ensuring that claims about sustainability are supported by verifiable data and certification. Overly simplistic or exaggerated messaging risks eroding trust if actual environmental gains are modest.

Community advocates emphasized the need for two-way dialogue, where residents can voice concerns and expectations rather than just receiving promotional materials. Public forums, social media channels, and community outreach programs can facilitate transparent exchanges about SAF's limitations and potential. This reciprocal communication style helps mitigate fears that local inhabitants often harbor about aviation growth—ranging from noise pollution to displacement if airport expansions occur. Through inclusive engagement, the aviation sector can demonstrate genuine responsiveness to community priorities.

Cost sensitivity also shapes public perception. Travelers who notice fare increases linked

to SAF usage might question the added value, especially if air pollution remains visibly high or if alternative travel methods are cheaper (Bryman & Bell, 2015). A robust communication plan that outlines SAF's environmental payoffs, such as reduced particulate matter or improved health outcomes, can legitimize moderate fare adjustments. Government subsidies or transparent carbon offset programs could alleviate public concerns regarding equity and affordability.

Demographic factors may further influence how different segments of Skopje's population perceive SAF. Younger, environmentally conscious travelers often display more willingness to embrace green initiatives, even at a premium. Older or economically constrained individuals may prioritize affordability over sustainability, indicating that targeted messages and policies might be required to address diverse attitudes. Recognizing these subgroup differences can refine marketing strategies, ensuring broad-based public acceptance rather than a one-size-fits-all approach.

Environmental NGOs and academic institutions can enhance public trust by serving as independent validators of SAF's benefits. When such organizations confirm reduced emissions and health improvements, skeptical citizens may become more receptive. Conversely, if NGOs criticize SAF's feedstock sourcing or question net emission reductions, they can significantly dampen public enthusiasm. Collaborating with credible third-party entities fosters accountability, offering a balanced perspective that resonates with both critics and supporters (ATAG, 2020).

Interviewees frequently noted the symbolic power of visible changes at Skopje International Airport. Activities like showcasing newly installed SAF storage tanks or celebrating the first commercial flight fueled partly by SAF can generate media interest and civic pride. Such milestones demonstrate tangible progress, countering perceptions that environmental policies seldom translate into real-world improvements. Media coverage of these events can thus catalyze broader conversations about green aviation, reinforcing positive public sentiment.

In some instances, negative historical experiences with environmental projects have bred public distrust in new initiatives. Community members recalled cases where promised ecological benefits never materialized or budgets were misappropriated. To preempt

similar skepticism with SAF, transparent governance, open financial reporting, and adherence to strict sustainability certifications are essential. Demonstrating accountability at every step—from feedstock procurement to emission monitoring—helps rebuild confidence that SAF is a genuine, beneficial transformation rather than a superficial “green” trend.

Policymakers agreed that cultural and social values could shape how communities evaluate SAF. Societies that prize environmental stewardship may more readily embrace a new fuel, while others grappling with economic hardships may remain ambivalent unless tangible job creation or direct health improvements become evident. This contextual dimension reaffirms the importance of tailoring public outreach to local realities, aligning SAF initiatives with broader socio-economic objectives. By situating SAF adoption within a holistic narrative of urban development and well-being, advocates can foster stronger public alignment.

A critical insight from interviews is the role of education in shaping public attitudes long-term. Incorporating lessons on renewable fuels and aviation’s environmental impact into school curricula or community workshops can cultivate early awareness. Younger generations who grow up understanding SAF’s importance may normalize sustainable travel choices, eventually influencing family and societal norms. Such generational shifts reinforce how public perception evolves gradually, underscoring the need for consistent, long-term engagement rather than isolated campaigns.

Stakeholders highlighted the value of public perception research, such as surveys or focus groups, to continuously gauge acceptance levels and refine communication strategies. These studies can track changes in sentiment over time, evaluating whether new policies or pilot programs shift attitudes positively or negatively. By systematically monitoring public opinion, policymakers and industry leaders can adjust outreach methods, address misconceptions, and highlight success stories related to SAF adoption.

5.4 Opportunities for SAF Integration in Skopje

Amid the challenges outlined, significant opportunities exist for integrating Sustainable Aviation Fuels into the aviation sector in Skopje. Interviewees identified multiple entry points, from leveraging EU funding to piloting innovative local feedstocks, each capable of

propelling SAF from a niche concept to a viable, mainstream option. Exploiting these opportunities hinges on cohesive planning, sustained cooperation among stakeholders, and adaptive policy frameworks that reward early adoption and steady progress.

One of the most promising opportunities lies in public-private partnerships, leveraging government support and private investment to build production facilities, storage infrastructure, and distribution networks (Norwegian Environment Agency, 2020). By sharing the financial risk, these partnerships can attract global SAF technology providers and feedstock suppliers, fostering localized expertise. Such synergy accelerates technology transfer and job creation while solidifying Skopje's capacity to produce and supply SAF efficiently.

Skopje could also position itself as a regional SAF hub, capitalizing on its strategic location and emerging market potential. By investing in large-scale refining facilities and advanced supply chains, the city could serve airlines from neighboring countries, lowering costs through economies of scale. Interviewees from the aviation sector suggested that early, robust infrastructure investments could anchor Skopje's competitive advantage in Southeastern Europe, drawing carriers eager to reduce their carbon footprints under upcoming international regulations.

Innovation and research present another avenue for opportunity. Collaborations with local universities, research institutes, and technology firms can drive breakthroughs in feedstock optimization, refining methods, and emissions tracking (European Commission, 2019). Governments can offer grants or tax incentives encouraging scientists and entrepreneurs to develop next-generation SAF solutions tailored to Macedonia's agricultural landscape. Successful innovations can be patented or licensed internationally, positioning the region as a thought leader in sustainable aviation.

A robust policy framework introducing blending mandates, tax reductions, or carbon pricing offers significant potential to accelerate SAF uptake. Such policies not only stimulate local production by ensuring a steady demand but also attract international companies looking for clear, forward-thinking legislative environments (European Commission, 2021). Policymakers can build on successful models from other European nations, adapting them to Skopje's economic context. This policy-driven approach fosters

a fertile environment where SAF investments flourish under predictable rules.

Interviewees mentioned the RefuelEU Aviation initiative, which, if embraced by North Macedonia, could facilitate smoother alignment with EU standards and unlock dedicated funds (ICAO, 2021). Proactive participation in cross-border programs fosters knowledge exchange and shared regulatory frameworks, easing challenges like certification and standardization. By integrating into pan-European networks, Skopje's airport and aviation enterprises may gain access to technical resources, best practices, and collaborative ventures spanning production to deployment.

Circular economy principles also underpin compelling opportunities for SAF in Skopje. Converting agricultural or municipal waste into sustainable jet fuel provides dual benefits of pollution reduction and resource efficiency. This approach alleviates landfill pressures and transforms waste streams into high-value products, resonating with rising global trends toward zero-waste solutions (UNEP, 2020). Local governments can invest in waste-collection improvements, forging supply agreements that benefit both environmental services and SAF producers.

Growing consumer awareness of environmental issues can be harnessed through eco-marketing strategies, a point repeatedly underscored by aviation stakeholders. Airlines might brand certain flights or routes as "green," catering to passengers willing to pay a premium for lower-carbon travel. Although niche at first, this market could expand as younger, climate-conscious travelers dominate future tourism and business travel (ATAG, 2020). By positioning Skopje as a pioneering green destination, the city could attract visitors specifically drawn to sustainable travel experiences.

Expanding the SAF ecosystem also opens opportunities for local entrepreneurship. Start-ups focusing on feedstock supply, refining technology, logistics optimization, or carbon accounting could flourish if policy environments encourage innovation. Incentives such as incubator programs, low-interest loans, or simplified business registration can nurture a domestic SAF supply chain. Over time, this growing ecosystem not only supports aviation but potentially diversifies and strengthens Skopje's broader economic fabric.

At the regional cooperation level, Macedonia can collaborate with neighboring countries to build shared SAF infrastructure or coordinate feedstock supply chains. Cross-border

projects reduce redundancies, capitalize on each country's competitive advantages, and distribute risks (ICAO, 2021). Interviewees indicated that certain feedstocks might thrive in bordering regions, while refining capacity could concentrate in another area. Such synergy fosters cost efficiency, making SAF more accessible for all participating nations and boosting the region's collective sustainability.

As climate finance expands, opportunities to secure international funding for SAF initiatives also rise. Bodies like the Green Climate Fund or European Investment Bank often prioritize projects that deliver measurable emission reductions and align with Sustainable Development Goals (UNFCCC, 2021). By constructing well-structured proposals supported by robust emission-reduction data, Skopje's aviation stakeholders can compete for significant grants or concessional loans. This external financing can offset high capital expenditures, fast-tracking SAF's commercial viability.

Interviewees suggested that multi-stakeholder platforms could be leveraged for knowledge sharing, strategy formulation, and collaborative problem-solving. These platforms could unite policymakers, airline representatives, environmental NGOs, fuel producers, and academic experts, fostering a culture of transparency and innovation. By exchanging best practices, identifying overlaps in resource needs, and resolving bottlenecks, participants can jointly shape a cohesive SAF roadmap. Such forums bolster trust, ensuring each group feels invested and heard as SAF integration progresses.

Additionally, export potential may materialize if local SAF producers manage to achieve surplus capacity. Airlines operating routes throughout Europe or beyond might favor sourcing fuel from Skopje if the product is cost-competitive and meets global certification standards. Gaining a foothold in export markets ensures demand remains robust, reinforcing economic stability for SAF enterprises. This dynamic could transform the city into a net exporter of green aviation solutions, extending the benefits of local investments across international borders.

5.5 Potential Impact of SAF on Skopje's Environment

The widespread adoption of Sustainable Aviation Fuel in Skopje could yield transformative environmental impacts, affecting air quality, climate resilience, and ecological stewardship. As an integral part of a broader sustainability strategy, SAF usage stands to significantly

reduce aviation-related emissions, curb noise pollution, and foster a greener urban ecosystem. These changes, although gradual, could reposition Skopje's environmental status regionally and even internationally, showcasing how targeted policy and industry collaboration can revitalize cityscapes.

The immediate impact of SAF often manifests through reduced particulate matter and sulfur emissions, contributing to cleaner air for neighborhoods surrounding the airport (ICAO, 2021). Over time, cumulative improvements in air quality can enhance public health outcomes, decreasing asthma incidence and other respiratory conditions linked to airborne pollutants (ATAG, 2020). With Skopje historically contending with poor air quality, even moderate shifts in aviation emission profiles can accelerate overall environmental improvement.

In the longer term, SAF's potential for cutting greenhouse gas emissions can fortify the city's resilience against climate change. Lower carbon intensity in aviation helps North Macedonia align with global decarbonization targets, contributing to temperature stabilization efforts critical for mitigating extreme weather patterns. Policymakers cited the heightened risk of heatwaves and climate-induced resource constraints, underscoring the value of aviation reforms as part of a cohesive national climate strategy.

Eco-friendly aviation fuel usage also extends intangible benefits to Skopje's urban ambiance, particularly if paired with improved land-use practices. Allocating green spaces near the airport and promoting reforestation projects can synergize with SAF's lower emission profile, further cushioning nearby communities from noise and particulate matter. Over time, these initiatives can spur a regenerative cycle of ecological renewal, reinforcing Skopje's identity as a city proactively tackling both pollution and climate adaptation.

A shift toward SAF resonates with biodiversity objectives, particularly if feedstock sources adopt sustainable cultivation practices. Reducing the reliance on fossil fuels may lessen the exploration and extraction activities that degrade habitats elsewhere. Meanwhile, responsible feedstock production fosters soil health, water conservation, and minimized chemical usage (European Commission, 2019). By embedding ecological considerations into SAF supply chains, Skopje can mitigate harmful impacts while cultivating positive outcomes across agricultural and natural landscapes.

The social dimension of environmental impact emerged in interviews, highlighting potential improvements in community well-being. Cleaner skies and reduced noise can enhance daily living for residents near the airport, boosting property values and quality of life. When combined with job creation in SAF production, distribution, or research, environmental gains intersect with socio-economic benefits, advancing multiple pillars of sustainable development. Many participants viewed this holistic approach as essential for building widespread support for SAF.

Moreover, adopting SAF can catalyze environmental innovation beyond aviation. Technological spillovers from advanced refining processes could inform green solutions in other industries, from bio-based plastics to biochemical production. Similarly, the impetus to reduce carbon footprints in aviation might expand into ground transportation, encouraging electric vehicles or alternative fuels for buses and freight. By acting as a linchpin for broader sustainability shifts, SAF positions Skopje as a hub of clean-tech innovation.

From a policy standpoint, environmental improvements facilitated by SAF offer diplomatic leverage. North Macedonia's progress in green aviation could strengthen relationships with European institutions, opening doors to additional funding, partnerships, and knowledge exchange (European Commission, 2021). Demonstrating measurable, positive environmental transformations through SAF usage can underscore the country's readiness to integrate deeper into European sustainability frameworks, reinforcing both environmental and geopolitical aspirations.

Increased stakeholder collaboration around SAF might also foster a culture of environmental stewardship in Skopje, uniting community, government, and industry leaders around a common objective. As tangible improvements become evident, such as clearer skies or decreased respiratory complaints—citizens may grow more receptive to additional green policies. This cultural shift can have lasting repercussions, creating momentum for environmental initiatives in waste management, water conservation, and renewable energy adoption.

While the potential impacts are largely positive, interviewees warned against overlooking possible unintended consequences. For instance, a surge in feedstock demand may

encourage unsustainable agricultural expansions or resource exploitation if oversight is weak (ICAO, 2021). Additionally, a myopic focus on SAF could divert attention from other, more cost-effective measures to reduce emissions, such as operational efficiencies and ground transport electrification. Ensuring synergy among multiple environmental strategies is vital for maximizing overall ecological benefits.

Another consideration involves distributional effects: some communities might benefit more visibly than others, especially if they live closer to the airport or near new SAF facilities. Balancing these geographic inequalities calls for holistic urban planning, ensuring that improvements—be they in air quality, job opportunities, or infrastructure—are equitably distributed. Policymakers may need to evaluate baseline environmental conditions across different neighborhoods to ensure SAF-driven gains do not inadvertently exacerbate socio-economic divides.

Skeptics highlight that scalability remains crucial for meaningful environmental impact. Minimal SAF usage might yield token improvements, insufficient to address Skopje's more entrenched pollution challenges. Consequently, large-scale adoption, robust policy support, and industry commitment are necessary to truly bend the emissions curve. As scaling occurs, regulatory vigilance must guard against greenwashing, ensuring that SAF usage is genuinely reducing net emissions and not just redistributing pollution across different segments of the supply chain.

6 Conclusion

In this Master's thesis, the importance, challenges, and opportunities surrounding the adoption of Sustainable Aviation Fuels (SAF) have been thoroughly explored, with a particular focus on their implementation in Skopje, North Macedonia. The research aimed to investigate not only the environmental benefits of SAF but also the economic, regulatory, and societal dimensions that influence their integration into the aviation sector. Through a combination of literature review, policy analysis, and qualitative interviews with key stakeholders, this study has provided a comprehensive and multi-perspective view on the role that SAF can play in supporting sustainable aviation and contributing to North Macedonia's environmental and developmental goals.

One of the key findings of the research is that SAF has the potential to significantly reduce carbon dioxide emissions, particulate matter, and other harmful pollutants when compared to traditional fossil-based aviation fuels. These benefits align with broader international climate agreements such as the Paris Accord and the EU Green Deal, providing Skopje with an opportunity to demonstrate leadership in the Western Balkans in terms of aviation sustainability. The interviews conducted with aviation professionals, environmental experts, policymakers, and community representatives confirmed a growing awareness of the environmental urgency and the strategic value that SAF holds, not only in reducing emissions but also in improving public health and strengthening energy resilience.

However, the research also revealed that the road to SAF implementation is complex and fraught with challenges. Chief among these are the high production costs of SAF, limited availability of sustainable feedstocks, and insufficient regulatory frameworks that currently do not mandate or adequately support SAF usage. Furthermore, infrastructural limitations at Skopje International Airport, a lack of public awareness, and fragmented institutional coordination further complicate the integration process. The absence of blending mandates or tax incentives, combined with a general lack of national-level strategy on sustainable aviation, has resulted in uncertainty for both investors and airline operators, delaying necessary innovations.

Despite these obstacles, the thesis identifies several tangible opportunities that can serve as catalysts for SAF adoption. These include public-private partnerships to reduce

financial risks, participation in EU-funded programs such as RefuelEU Aviation, and investments in local innovation through universities and research institutions. The potential to establish Skopje as a regional SAF hub also emerged as a strategic opportunity, particularly if coupled with circular economy principles that promote the use of local waste and agricultural residues for SAF production. By embracing a phased approach and aligning with international standards, North Macedonia can foster an enabling environment that encourages sustainable practices while attracting international collaboration and investment.

The stakeholder interviews proved instrumental in shaping the recommendations of this thesis. The qualitative data underscored the importance of trust-building, transparent communication, and community involvement in the transition toward SAF. It became clear that technical solutions alone will not suffice unless accompanied by public engagement, inclusive policy-making, and educational initiatives that explain SAF's benefits in accessible terms. Integrating these social and governance dimensions is critical for long-term success and for ensuring that the benefits of SAF adoption are equitably distributed across different societal groups.

In summary, the transition to Sustainable Aviation Fuels represents both a challenge and an opportunity for Skopje and North Macedonia as a whole. While the economic and regulatory hurdles are significant, the environmental, health, and reputational benefits make SAF a strategic priority for sustainable development. This thesis has highlighted the multidimensional nature of the SAF ecosystem and the importance of coordinated efforts among government agencies, the private sector, academia, and civil society. Moving forward, policy coherence, financial innovation, and stakeholder engagement will be essential pillars in ensuring that SAF fulfills its promise as a key component of green aviation and sustainable urban development in the years to come.

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References

- Airbus. n.d. Our approach to sustainability. (n.d.). URL: <https://www.airbus.com/en/sustainability/our-approach-to-sustainability>. Accessed: 1 April 2025
- Armstrong, R. C., et al. 2016. The feasible use of jet fuel derived from biomass feedstocks. *Biofuels, Bioproducts and Biorefining*, 10(1), 13–22.
- Air Transport Action Group. 2020. Waypoint 2050: A vision for aviation’s sustainable future. URL: https://aviationbenefits.org/media/167187/w2050_full.pdf. Accessed: 16 January 2025
- ASTM International. 2016. ASTM D7566: Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. URL: <https://store.astm.org/d7566-16a.html>. Accessed: 2 May 2024
- Bryman, A., & Bell, E. 2015. *Business research methods* (4th ed.). Oxford University Press. United Kingdom. E-book. Accessed: 14 February 2025
- BIO4A. 2020. Advanced sustainable biofuels for aviation. URL: <https://www.bio4a.eu/>. Accessed: 19 August 2024
- Boeing. n.d. Sustainability: Climate and environment. URL: <https://www.boeing.com/sustainability/introduction>. Accessed: 1 April 2025
- Biofuels Digest. 2024. Global SAF market to expand at a CAGR of 61% from 2023 to 2030, study finds. URL: <https://www.biofuelsdigest.com/bdigest/global-saf-market-to-expand-at-a-cagr-of-61-from-2023-to-2030-study-finds/>. Accessed: 18 January 2025
- Braun, V., & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. URL: <https://doi.org/10.1191/1478088706qp063oa>. Accessed: 20 May 2024
- Bergin, M. H., et al. 2018. Real-time measurements and simulation of jet engine particulate emissions: implications for aviation emission standards. *Environmental Science & Technology*, 52(4), 2497–2506.

- Creswell, J. W. 2009. Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed.). SAGE Publications. California. E-book. Accessed: 14 June 2025
- CAAFI. 2021. Commercial Aviation Alternative Fuels Initiative. URL: <https://www.caafi.org>. Accessed: 16 June 2024
- Chiaramonti, D. 2019. Sustainable aviation fuels: The challenge of decarbonization. Energy Procedia, 158, 1202–1207.
URL: <https://doi.org/10.1016/j.egypro.2019.01.308>. Accessed: 16 February 2024
- Chiaramonti, D., Prussi, M., Buffi, M., & Tacconi, D. 2019. Sustainable aviation fuels: the challenge of decarbonizing heavy transport. Applied Energy, 264, 114601.
- Corsatea, T., & Marchisio, M. 2021. Policy options to support the adoption of sustainable aviation fuels. Renewable and Sustainable Energy Reviews, 138, 110667.
- de Jong, S., Antonissen, K., Hoefnagels, R., et al. 2017. Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production. Biotechnology for Biofuels, 10(64).
URL: <https://doi.org/10.1186/s13068-017-0739-7>. Accessed: 23 July 2024
- Energy Community Secretariat. 2020. Transport Decarbonization in the Western Balkans. URL: <https://www.energy-community.org/documents/secretariat.html>. Accessed: 11 March 2025
- European Parliament. 2022. Proposal for a Regulation on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation). URL: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52021PC0561>. Accessed: 1 July 2024
- EASA. n.d. SAF market. URL: <https://www.easa.europa.eu/en/domains/environment/eaer/sustainable-aviation-fuels/saf-market>. Accessed: 22 July 2024
- EASA. 2022. European Aviation Environmental Report 2022. URL: https://www.easa.europa.eu/sites/default/files/eaer-downloads//230217_EASA%20EAER%202022.pdf. Accessed: 11 October 2024

EASA. 2023. Sustainable Aviation Fuels (SAF). URL: <https://www.easa.europa.eu/en/domains/environment/sustainable-aviation-fuels-saf>. Accessed: 11 October 2024

European Union. 2018. Directive (EU) 2018/2001 on the Promotion of the Use of Energy from Renewable Sources. URL: <https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng>. Accessed: 2 July 2024

European Court of Auditors. 2022. Review 01/2022: Energy taxation, carbon pricing and energy subsidies. URL: https://www.eca.europa.eu/en/publications/RW22_01. Accessed: 18 November 2024

European Technology and Innovation Platform on Bioenergy. 2021. SAF R&D priorities. Advanced Biofuels Conference 2019. Available: <https://old.etipbioenergy.eu/advanced-bio-fuels-conference-2019>. Accessed: 21 September 2024

ECAC. 2021. Environmental strategy 2022–2030: ECAC's strategy for the future. URL: https://www.ecac-ceac.org/images/documents/ECAC_Strategy_for_the_Future_2021.pdf. Accessed: 9 December 2024

Elgowainy, A., Han, J., Wang, M., Carter, N., Stratton, R., & Hileman, J. 2012. Life-cycle analysis of alternative aviation fuels in GREET. Argonne National Laboratory. URL: <https://publications.anl.gov/anlpubs/2016/05/127787.pdf>. Accessed: 18 June 2024

European Commission. n.d. Sustainable & smart mobility. URL: https://transport.ec.europa.eu/transport-themes/eu-mobility-transport-achievements-2019-2024/sustainable-smart-mobility_en. Accessed: 6 June 2024

European Commission. 2018. Renewable Energy Directive II. URL: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en#directive-20182001eu. Accessed: 10 April 2024

European Commission. 2019. EU Green Deal. URL: https://eur-lex.europa.eu/source.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF. Accessed: 17 November 2024

European Commission. 2020a. EU Emissions Trading System (EU ETS). URL: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en. Accessed: 24 April 2024

European Commission. 2020b. Circular Economy Action Plan. URL: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en. Accessed: 13 November 2024

European Commission. 2021. ReFuelEU Aviation Initiative. URL: https://transport.ec.europa.eu/transport-modes/air/environment/refueleu-aviation_en. Accessed: 15 November 2024

Eurocontrol. 2022. Eurocontrol Aviation Outlook 2050. URL: <https://www.eurocontrol.int/publication/eurocontrol-aviation-outlook-2050>. Accessed: 8 August 2024

Fusch, P. I., & Ness, L. R. 2015. Are we there yet? Data saturation in qualitative research. *The Qualitative Report*, 20(9), 1408–1416. URL: <https://doi.org/10.46743/2160-3715/2015.2281>. Accessed: 18 January 2025

Ghosh, B., & Lee, K. 2018. Impact of sustainable aviation fuels on aircraft emissions and air quality. *Environmental Research Letters*, 13(5), 054002.

Hannula, I., & Reiner, D. 2019. Power-to-liquid and power-to-gas pathways for the integration of renewables into the energy system. *Environmental Science & Technology*, 53(7), 3682-3693.

Hileman, J., & Stratton, R. 2014. Alternative jet fuel feasibility. *Transport policy*, 34, 52-62. Elsevier. URL: <https://doi.org/10.1016/j.tranpol.2014.02.018>. Accessed: 31 May 2024

Hileman, J., et al. 2010. Life-cycle greenhouse gas emissions of alternative aviation fuels. *Environmental Science & Technology*, 44(7), 2689-2694.

ICAO. n.d. Global Framework for Aviation Alternative Fuels (GFAAF). URL: <https://www.icao.int/environmental-protection/GFAAF>. Accessed: 3 March 2025

ICAO. 2017. Sustainable aviation fuels guide. URL: https://www.icao.int/environmental-protection/knowledge-sharing/Docs/Sustainable%20Aviation%20Fuels%20Guide_vf.pdf. Accessed: 27 February 2025

ICAO. 2018. Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). URL: <https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx>. Accessed: 30 November 2024

ICAO. 2019a. CAEP Fuels Task Group. URL: <https://www.icao.int/environmental-protection/pages/CAEP-FTG.aspx>. Accessed: 20 November 2024

ICAO. 2019b. ICAO Environmental Report 2019. International Civil Aviation Organization. URL: <https://www.icao.int/environmental-protection/Pages/envrep2019.aspx>. Accessed: 29 April 2024

ICAO. 2019c. First ICAO Stocktaking Seminar toward the 2050 Vision for Sustainable Aviation. URL: <https://www.icao.int/Meetings/SAFStocktaking/Pages/default.aspx>. Accessed: 1 December 2024

ICAO. 2020a. Sustainable Aviation Fuels Guide. URL: https://www.icao.int/environmental-protection/knowledge-sharing/Docs/Sustainable%20Aviation%20Fuels%20Guide_vf.pdf. Accessed: 1 December 2024

ICAO. 2020b. CORSIA Sustainability Criteria for CORSIA Eligible Fuels. URL: <https://www.icao.int>. Accessed: 29 April 2024

ICAO. 2021. SAF Life Cycle Emissions Analysis. Life Cycle Emissions of SAF. URL: https://www.icao.int/environmental-protection/pages/SAF_LifeCycle.aspx. Accessed: 4 December 2024

ICAO. 2022. Sustainability Criteria for CORSIA Eligible Fuels. URL: https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2005%20-%20Sustainability%20Criteria%20-%20November%202022.pdf. Accessed: 5 December 2024

ICAO. 2023. SAF Stocktaking Report. URL: <https://www.icao.int/Meetings/Stock-taking2023/Documents/2%20-%202023%20JH%20Stocktaking%20-%20Jane%20Scene%20Setting.pdf>. Accessed: 2 December 2024

IATA. 2015. IATA Guidance Material for Sustainable Aviation Fuel Management. URL: <https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/safr-1-2015.pdf>. Accessed: 1 August 2024

IATA. 2021. Fly Net Zero. International Air Transport Association. URL: <https://www.iata.org/en/programs/sustainability/flynetzero>. Accessed: 1 August 2024

IATA. 2022. Net Zero Roadmap for Aviation. URL: <https://www.iata.org/contentassets/4b18fa1ac4a246879c058cf75954dbda/netzero-roadmaps-presentation-agm2023.pdf>. Accessed: 10 September 2024

IATA. 2023. Update on Sustainable Aviation Fuels (SAF). URL: <https://www.iata.org/contentassets/0d0d6241acbe4947a6222bb9beb42592/saf-presentation-agm2023.pdf>. Accessed: 26 February 2025

International Energy Agency. 2020. Sustainable Aviation Fuels: A pathway to net-zero emissions for aviation. International Energy Agency. URL: <https://www.iea.org>. Accessed: 17 May 2024

IRENA. 2021. Reaching zero with renewables: Biojet fuels. URL: <https://www.irena.org/publications/2021/Jul/Reaching-Zero-with-Renewables-Biojet-Fuels>. Accessed: 30 December 2024

IPCC. 2022. Mitigation of climate change – Transport sector chapter. URL: <https://www.ipcc.ch/report/ar6/wg3/>. Accessed: 18 February 2025

ICCT. 2021a. Fueling flight: Assessing the sustainability implications of alternative aviation fuels. URL: <https://theicct.org/wp-content/uploads/2021/06/Alt-aviation-fuel-sustainability-mar2021.pdf>. Accessed: 14 November 2024

- ICCT. 2021b. Estimating sustainable aviation fuel feedstock availability to meet growing European Union demand. URL: <https://theicct.org/wp-content/uploads/2021/06/Sustainable-aviation-fuel-feedstock-eu-mar2021.pdf>. Accessed: 23 April 2024
- ICCT. 2024. Availability of biomass feedstocks in the European Union to meet the 2035 ReFuelEU Aviation SAF target. URL: <https://theicct.org/publication/low-risk-biomass-feedstocks-eu-refueleu-aug24/>. Accessed: 19 February 2025
- Kvale, S., & Brinkmann, S. (2015). *InterViews: Learning the craft of qualitative research interviewing* (3rd ed.). SAGE Publications. California. E-book. Accessed: 25 February 2025
- KPMG International. 2022. Decarbonising ground operations: A long-haul journey. URL: <https://assets.kpmg.com/content/dam/kpmg/ie/pdf/2022/09/ie-aviation-2030-decarbonisation-of-ground-ops.pdf>. Accessed: 19 October 2024
- Lynch, J., et al. 2017. The global carbon intensity of crude oil production. *Science*, 356(6343), 61-65.
- Lincoln, Y. S., & Guba, E. G. 1985. *Naturalistic inquiry*. SAGE Publications. California. E-book. Accessed: 25 January 2025
- Lufthansa Group. 2021. SASB Report 2021. URL: <https://www.lufthansagroup.com/media/downloads/en/responsibility/LH-SASB-Report-2021.pdf>. Accessed: 30 January 2025
- Moore, R. H., et al. 2017. Biofuel blending reduces particle emissions from aircraft engines at cruise conditions. *Nature*, 543(7645), 411-415. URL: <https://doi.org/10.1038/nature21420>. Accessed: 12 May 2024
- MOEPP of the Republic of North Macedonia. 2015. Macedonian air quality assessment report for the period 2005–2015. URL: <https://www.moep.gov.mk/wp-content/uploads/2023/10/Air%20quality%20assessment%20report%202005-2015eng.pdf>. Accessed: 9 September 2024
- MOEPP of the Republic of North Macedonia. 2021. *National Climate Change Adaptation Action*

Plan. URL: <https://api.klimatskipromeni.mk/data/rest/file/download/f202dd06e0b5f69a01fe7e29deb9a17033763eb4246747fb75152163cb9f4a91.pdf>. Accessed: 10 September 2024

McKinsey & Company. 2024. How the aviation industry could help scale sustainable fuel production. URL: <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/how-the-aviation-industry-could-help-scale-sustainable-fuel-production>. Accessed: 20 October 2024

NREL. 2019. Sustainable Aviation Fuel: A Review of Technical Pathways. National Renewable Energy Laboratory. URL: www.nrel.gov. Accessed: 8 June 2024

NREL. 2023. Accelerating sustainable aviation fuel technology from laboratory to deployment: An overview of NREL's sustainable aviation fuel pathways. U.S. Department of Energy. URL: www.nrel.gov/docs/fy23osti/87156.pdf. Accessed: 24 May 2024

NREL. 2024. Sustainable aviation fuel blending and logistics. U.S. Department of Energy. URL: <https://www.nrel.gov/docs/fy24osti/90979.pdf>. Accessed: 23 August 2025

NASA. 2023. NASA, partners explore sustainable fuel's effects on aircraft contrails. NASA Armstrong Flight Research Center. URL: <https://www.nasa.gov/centers-and-facilities/armstrong/nasa-partners-explore-sustainable-fuels-effects-on-aircraft-contrails/>. Accessed: 31 January 2025

Norwegian Ministry of Climate and Environment. 2021. Norway's Climate Action Plan for 2021–2030. URL: <https://www.regjeringen.no/contentassets/a78ecf5ad2344fa5ae4a394412ef8975/en-gb/pdfs/stm202020210013000engpdfs.pdf>. Accessed: 20 December 2024

Neste. 2022. How is Neste MY SAF made. URL: <https://www.neste.com/products-and-innovation/sustainable-aviation/sustainable-aviation-fuel>. Accessed: 28 January 2025

OECD. 2022. OECD guidance on transition finance: Ensuring credibility of corporate climate transition plans. URL: https://www.oecd.org/content/dam/oecd/en/publications/reports/2022/10/oecd-guidance-on-transition-finance_ac701a44/7c68a1ee-en.pdf. Accessed: 6 May 2024

Pavlenko, N., Searle, S., & Christensen, A. 2019. The cost of supporting alternative jet fuels in the European Union. International Council on Clean Transportation.

URL: theicct.org/sites/default/files/publications/Alternative_jet_fuels_cost_EU_20190320.pdf. Accessed: 31 July 2024

Publications Office of the European Union. 2021. Study supporting the impact assessment of the ReFuelEU Aviation initiative. URL: <https://op.europa.eu/en/publication-detail/-/publication/46892bd0-0b95-11ec-adb1-01aa75ed71a1>. Accessed: 12 September 2024

PwC. n.d. Climate and sustainability insight. URL: <https://www.pwc.com/gx/en/issues/esg.html>. Accessed: 2 January 2025

Patton, M. Q. 2015. Qualitative research & evaluation methods: Integrating theory and practice (4th ed.). SAGE Publications. California. E-book. Accessed: 15 March 2025

Roundtable on Sustainable Biomaterials. 2020. RSB Certification. URL: <https://rsb.org>. Accessed: 30 June 2024

Resources for the Future. 2024. Supporting policies for sustainable aviation fuels: Key areas for further research. URL: <https://www.resources.org/common-resources/supporting-policies-for-sustainable-aviation-fuels-key-areas-for-further-research/>. Accessed: 21 November 2024

RAND Corporation. 2025. Decarbonizing aviation with electrochemical fuels: Challenges and opportunities for carbon dioxide-based solutions for reducing greenhouse gas emissions from air travel. URL: <https://doi.org/10.7249/RRA3118-1>. Accessed: 10 December 2024

Resilient Skopje: Climate Change Strategy. 2017. URL: <https://skopje.gov.mk/media/4051/resilient-skopje-strategy-eng.pdf>. Accessed: 10 September 2024

Shell Aviation. 2021. Driving decarbonisation from 'what' to 'how'. URL: <https://www.shell.com/DecarbonisingAviation>. Accessed: 8 March 2025

Schäfer, A. W., et al. 2019. The contribution of aviation to climate change: Current and future impacts. Environmental Research Letters, 14(8), 084019.

- Sustainable Aviation UK. 2020. Sustainable Aviation Fuels Roadmap. URL: https://www.sustainableaviation.co.uk/wp-content/uploads/2020/02/SustainableAviation_FuelReport_20200205.pdf. Accessed: 26 January 2025
- Searle, S., Pavlenko, N., & Comer, B. 2018. Potential greenhouse gas savings from a 2030 greenhouse gas reduction target with indirect emissions accounting for the European Union. International Council on Clean Transportation. URL: https://theicct.org/wp-content/uploads/2021/06/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf. Accessed: 23 August 2024
- SkyNRG. 2020. Overview of SAF Mandates. URL: <https://skynrg.com>. Accessed: 7 July 2024. Accessed: 26 June 2024
- SkyNRG. n.d. SAF supply chain analysis. Available: <https://skynrg.com/fly-with-saf/saf-for-airlines/supply-chain/>. Accessed: 7 May 2024
- Smith, P., et al. 2014. Agriculture, Forestry and Other Land Use (AFOLU). In Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. URL: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter11.pdf. Accessed: 25 March 2024
- Staples, M. D., Malina, R., Suresh, P., Hileman, J. I., & Barrett, S. R. 2014. Lifecycle greenhouse gas footprint and minimum selling price of renewable diesel and jet fuel from advanced fermentation. *Energy & Environmental Science*, 7(5), 1545-1554.
- Staples, M. D., Malina, R., Suresh, P., Hileman, J. I., & Barrett, S. R. 2018. Aviation CO₂ emissions reductions from the use of alternative jet fuels. *Energy Policy*, 114, 342-354. URL: <https://doi.org/10.1016/j.enpol.2017.12.007>. Accessed: 11 August 2024
- Tilman, D., Socolow, R., Foley, J. A., et al. 2009. Beneficial biofuels - the food, energy, and environment trilemma. *Science*, 325(5938), 270-271.
- The Royal Society. 2023. Net zero aviation fuels: Resource requirements and environmental impacts. URL: <https://royalsociety.org/-/media/policy/projects/net-zero-aviation/net-zero-aviation-fuels-policy-briefing.pdf>. Accessed: 4 April 2025

Transport & Environment. 2024a. Aviation's climate problem: a sector with booming growth, that clean technologies alone won't be able to solve. URL: <https://www.transportenvironment.org/state-of-european-transport/state-of-transport/aviation>. Accessed: 10 January 2025

Transport & Environment. 2024b. Green aviation's make or break moment. URL: <https://www.transportenvironment.org/articles/green-aviations-make-or-break-moment>. Accessed: 6 April 2025

U.S Environmental Protection Agency (EPA). 2020. Renewable Fuel Standard Program. URL: <https://www.epa.gov>. Accessed: 11 May 2024

U.S. Department of Energy. 2022. SAF Grand Challenge Roadmap. Flight Plan for Sustainable Aviation Fuels. URL: <https://www.energy.gov/sites/default/files/2022-09/beto-saf-gc-roadmap-report-sept-2022.pdf>. Accessed: 19 January 2025

UNFCCC. 2015. Paris Agreement. URL: <https://unfccc.int>. Accessed: 11 May 2024

UN Environment Programme. 2021. Aviation emissions and climate change. In Emissions Gap Report 2021. URL: <https://www.unep.org/resources/emissions-gap-report-2021>. Accessed: 17 February 2025

U.S. Department of Energy. 2021. Sustainable Aviation Fuel Grand Challenge. URL: <https://www.energy.gov>. Accessed: 11 June 2024

U.S. Federal Aviation Administration (FAA). (2018). Aviation Emissions and Air Quality Handbook. URL: <https://www.faa.gov>. Accessed 12 June 2024

U.S. Federal Aviation Administration (FAA). 2022. Sustainable aviation fuels (SAF). URL: <https://www.faa.gov/media/74261>. Accessed: 17 September 2024

UK Department for Transport. 2021. Jet Zero Consultation Document. URL: <https://assets.publishing.service.gov.uk/media/60f01c51e90e0764c8f0a4c7/jet-zero-consultation-a-consultation-on-our-strategy-for-net-zero-aviation.pdf>. Accessed: 11 November 2024

Way, S., et al. 2020. The potential for biofuels to reduce lifecycle greenhouse gas emissions from aviation. *Environmental Science & Technology*, 54(6), 3537-3545.

Weyant, C., et al. 2017. The contribution of aircraft NO_x emissions to surface ozone and the resulting radiative forcing. *Atmospheric Environment*, 170, 33-41.

World Bank. 2020. State and Trends of Carbon Pricing 2020. URL: <https://openknowledge.worldbank.org/server/api/core/bitstreams/5afce9b5-03e0-5557-a550-6fac52275dde/content>. Accessed: 1 March 2024

World Bank. 2022. Decarbonizing air transport: Sustainable aviation fuels are vital for growth. URL: <https://blogs.worldbank.org/en/transport/decarbonizing-air-transport-sustainable-aviation-fuels-are-vital-growth>. Accessed: 19 March 2024

World Economic Forum. 2020. Clean Skies for Tomorrow. Sustainable Aviation Fuel: Ready for Take-off? URL: https://www3.weforum.org/docs/WEF_Clean_Skies_Tomorrow_SAF_Analytics_2020.pdf. Accessed: 11 October 2024

World Economic Forum. 2021a. Clean Skies for Tomorrow Coalition. URL: <https://www.weforum.org/focus/clean-skie-collection/>. Accessed: 18 July 2024

World Economic Forum. 2021b. Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation. URL: <https://www.weforum.org>. Accessed: 8 April 2024

Yeh, S., & Witcover, J. 2017. Status Review of California's Low Carbon Fuel Standard. Institute of Transportation Studies, University of California, Davis. URL: <https://escholarship.org/uc/item/445815cd>. Accessed: 24 March 2024

Zhou, Y., et al. 2019. Lifecycle assessment of aviation biofuels: A critical review. *Renewable and Sustainable Energy Reviews*, 104, 504-519.

Appendices

Appendix 1. Interviewees' Profile Summary

Expert A is a Government Official from the Ministry of Transport and Communications. Expert A organizes public hearings where the main topic is the high air pollution problem in Skopje. Those hearings aim to develop new measurements and practices that will improve the air quality and the overall public health of Skopje's citizens and the surrounding areas. Expert A emphasized his awareness of SAF implementation importance in reducing emissions from aviation fossil fuel combustion.

Expert B is a Government Representative from the Ministry of Environment. The expert is a part of the carefully selected team that works on developing a program that will reduce aviation emissions and polluting substances from other industrial sectors, which aims to protect the country's biodiversity and create a more sustainable future.

Expert C is a Civil Aviation Agency representative from North Macedonia. Moreover, Expert C took part in last year's training process related to the SAF's importance in terms of reducing the carbon footprint of the aviation sector. Furthermore, it was also mentioned that in our case, Skopje City will benefit significantly from the SAF's adoption since it is considered one of the most polluted cities worldwide.

Expert D is an Airport Operations Manager at Skopje International Airport. Expert D noted that the TAV airports are strongly committed to reaching the goal of decarbonizing the aviation industry by 2050. Moreover, a step further towards reaching their goal of working on a strategy and making Skopje International Airport a silent airport and reducing noise pollution as of February 2025.

Expert E is an Airline Sustainability Officer for a low-cost airline carrier that is also based in North Macedonia. Expert E is highly aware of the fact that the forthcoming government climate action and projects are playing a vital role in reducing the greenhouse gas emissions from the aviation sector, which simultaneously will improve the air quality in the capital city and surrounding areas. Furthermore, during the interview, it was acknowledged the importance of SAF fuel adoption in terms of reducing air pollution globally and locally.

Expert F is a representative of a leading private fuel supplier company in North Macedonia. Additionally, they are the primary kerosene distributor at the two airports in the country, which are located in Skopje and Ohrid. Expert F highlighted the economic considerations in terms of SAF implementation and distribution, such as higher cost and limited feedstock supply for its production.

Expert G is an Environmental Expert and works in the NGO sector. During the interview expert G noted that SAF is probably the most credible and realistic way to reduce CO₂ emissions to a larger extent and improve the air quality in Skopje. Therefore, joining the voluntary market of airport operators that adopted SAF to reduce emissions, despite the higher cost, must be taken into consideration.

Expert H is an academic expert from the Faculty of Mechanical Engineering in Skopje. Expert H highlighted the importance of government involvement and incentives, which are already happening in various countries worldwide to encourage SAF adoption.

Expert I is a representative of a Local Waste Management Company whose main activity is recycling all sorts of waste and keeping our planet as green as possible. The interviewee stated that SAF, as a concept, is not so familiar to the general public. Therefore, raising awareness about its importance would probably speed up the acceptance process and remove any doubts or skepticism. By doing that, we will be able to create a climate-resilient pathway and improve the air quality in Skopje and the surrounding areas.

Expert G is a Community Leader who represents a municipality near Skopje Airport. Moreover, he highlighted the environmental benefits of implementing SAF at Skopje Airport. Reducing aircraft noise pollution, improving the local air quality in the city of Skopje and surrounding areas, and reducing the impact of aviation emissions on global climate are just a few of the many goals that were mentioned during the interview.

Expert K is a Tourism Board representative of the City of Skopje. Consequently, she noted that SAF implementation will not only have a positive impact on Skopje's air pollution problem but also will improve our city's image and attract more tourists, which is good for the country's economy and will make North Macedonia a regional leader in sustainable aviation.

Expert L is an Energy Analyst and simultaneously an independent researcher who responded to the interview invitation. Expert L explained that even though SAF is not commercially viable at the moment, securing funding for SAF production facilities and technologies could lead us to create a climate-resilient pathway while reducing CO₂ emissions from the aviation sector.

Expert M is a Policy Advisor in the EU Integration Office in North Macedonia. Expert M's knowledge of our subject is based on international strategies for SAF adoption and EU legislation and standards. Moreover, it was noted that since North Macedonia is not yet an EU member, the government must work harder to enforce stronger regulatory frameworks to encourage SAF

adoption. Taking advantage of the EU grants and collaborating with governments on an international level would be a big step forward in aligning with the EU climate targets

Expert N is a SAF Technology Specialist at the largest oil distribution company in North Macedonia. As a start-up sector in their long-standing company, Expert N noted the high cost of SAF and the expensive SAF production technologies as a major concern, which at this moment makes it not commercially viable. However, he strongly believes that SAF adoption will have a positive impact on improving the air quality in Skopje and the city's environmental condition over time.

Expert O is a Public Health Expert from the Institute for Public Health. Expert O emphasized the impact of the aviation sector on Skopje's air pollution problem. Consequently, it was noted that SAF implementation at Skopje Airport will not only improve air quality, which is critical for Skopje, but also the overall public health of its citizens.

Appendix 2. Interview Questions

Awareness and Understanding of SAF

1. What is your understanding of Sustainable Aviation Fuel (SAF)?
2. How do you assess the current level of public awareness about SAF?
3. Do you think SAF can realistically be adopted in Skopje in the near future?

Environmental Benefits

4. How would SAF adoption impact air quality and public health in Skopje?
5. Could SAF contribute to improving North Macedonia's alignment with EU standards?
6. What is your vision for the future of aviation sustainability in our country?

Economic Feasibility

7. What are the biggest challenges for SAF integration in North Macedonia?
8. What kind of incentives do you believe would help promote SAF adoption?
9. Do you think airline companies are ready to shift to SAF despite higher costs?
10. Are there potential local feedstocks suitable for SAF production?

Regulatory and Policy Needs

11. Are there existing government policies that support SAF usage?
12. What regulatory changes are necessary to accelerate SAF use?
13. How can the government collaborate with the private sector to facilitate SAF integration?

Community and Collaborative Impact

14. Are there opportunities for collaboration between government, private sector, and academia?
15. What role should international organizations play in supporting SAF integration?
16. How can Skopje become a regional hub for sustainable aviation?