The Economic and Environmental Impact of ReFuelEU Aviation Regulation to Domestic Air Traffic in Finland

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Abstract

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Sustainability has become the topic of various research, and it is the subject in many aviation related issues. The environmental impact of aviation is a remarkable contributor to climate change due to its dependency of fossil fuels. Recently, the European Union has adopted new legislation which mandates the usage of sustainable aviation fuels to reduce emissions derived from air travel. The so called ReFuelEU Aviation regulation presents a gradually increasing amount of SAF required for every flight departing or arriving in the EU from 2025 onwards.

The objective of this thesis was to study the environmental and economic impact of the new legislation to the flight route between Helsinki and Kuopio. The effect of the regulations was approached by applying it to a single flight route in relatively small scope to provide an example case which could be applied to similar cases elsewhere. The scope of this study was limited to examine direct carbon emissions in scope 1. The economic impact was analyzed through the regulation's direct effect to fuel costs and costs derived from infrastructural or organizational changes were not included.

The research was conducted by employing two separate semi-structured interviews with the fuel supplier and operating airline. In addition, secondary research was utilized to create a thorough understanding of the regulatory framework. This data was then combined to create future scenarios for the different stages of implementation for years 2025, 2030, 2035, 2040, 2045, and 2050. The data was presented for single operations and additionally on an annual basis.

It was found in this study that the effect of the regulation is relatively small during the first years of implementation. Yet, the results of this research showed promising decrease in carbon emissions over the whole implementation period. The ratio of SAF blend was found being directly correlational with direct emissions reductions, indicating that the ratio of SAF can be reduced from overall carbon emissions. By the end of the implementation in 2050, the emissions reductions were predicted to be 70% from the current situation in 2024. However, the economic impact showed a dramatic increase in fuel costs as they are expected to rise by 175% during the implementation. This would mean a significant change to the cost structure and operational profits.

Key words
ReFuelEU Aviation regulation, environmental sustainability, carbon accounting, economic impact, domestic air travel.

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1 Introduction

This thesis is done as part of bachelor's degree of business administration degree programme in aviation business at Haaga-Helia University of Applied Sciences. The thesis is research oriented, and it examines a case study through qualitative research. The case of this research is to study the economic and environmental impact of ReFuelEU Aviation regulation to a regional flight route in Finland. Applying the regulation to an example in smaller scale facilitates the understanding of its effects and allows to examine the details. The objective is to provide results which could be reflected to similar flight routes affected by the same regulation.

The context of this research is the increasing requirements towards environmental sustainability in the aviation industry, and changing EU legislation which will impact every member state in the European Union. Sustainability has been the center of discussion in every field since biodiversity and climate change poses one of the greatest risks for the economy and human well-being. Sustainability is a larger concept which consists of environmental, social, and governmental aspects. However, this thesis is limited to study environmental sustainability specifically.

The topic was selected partially because of personal interest towards sustainability in aviation but additionally due to the industry's changing requirements for future experts. Understanding and practicing sustainable business is required from every field and especially from aviation in the modern context. The objective of this thesis is to apply my competences in aviation business and sustainable development. Understanding the principles of aviation business is necessary when applying carbon accounting metrics and sustainability practices due to its unique nature.

The rapidly changing regulatory environment in aviation requires expertise and research in the field. Therefore, the objective of this thesis is to develop personal competences by studying a real-life example. In addition, the objective is to provide reference for future research. The hope is that this thesis will develop and demonstrate my level of expertise in sustainable aviation.

1.1 Background of the Study

Aviation industry could be considered a mature business which means that the industry is well-established and has a relatively stable market. The industry has been around for decades and usually growth is slow, and airlines mainly focus on maintaining their market shares among competition. Aviation is notorious for its tight operational profit margins, and it is extremely volatile for changes and crisis happening in the operational environment. This has been recently proved yet again during the Covid-19 global pandemic.

Currently, aircraft rely almost exclusively on fossil jet fuels to operate which is explains why the aviation industry has been at center of discussion related to its climate change contribution. Aviation contributes to approximately 3.8% to the total GHG emissions in the European Union, whereas the whole transportation sector is at 13.9% (European Commission 2024). Environmental sustainability has become one of the most important or perhaps even the most important objective of our time. Environmental sustainability is a well-researched topic in the aviation industry but reducing emissions while accommodating growth is not an easy task. Technical development is still required to turn aviation into a climate positive industry, but new solutions and sustainable aviation fuels are currently a costly option.

Legislative organs like the European Union have started to take action to combat emissions from the aviation industry through regulatory measures. In 2019 the European Commission adopted a Communication on the European Green Deal, with the objective to reduce emissions of the transport sector by 90% by 2050. In 2021 the Fit for 55 package was presented by the Commission which included the ReFuelEU initiative. This initiative was eventually approved by the European Parliament, and the regulation would set in force in 2024 (European Parliament 2024). Even though the environmental impacts of aviation are well known, the new regulation for 2024 is still a relatively new topic in research. Therefore, it is beneficial for the industry to study the effects of changing regulatory environment and project their current state into the future.

1.2 Introduction of the Case

The case of this thesis is to study the domestic flight route between Helsinki and Kuopio in Finland. The route is currently operated by one airline which has requested to stay anonymous in this thesis. More specifically, this thesis will study the economic and environmental impact of ReFuelEU Aviation regulation to the selected flight route. The study is conducted by interviewing experts from the airline and fuel supplier to gather data which is applied to the regulatory framework of EU’s upcoming regulation. The desired outcome of this research is to gain an understanding of the future developments in fuel costs and CO2 emissions reductions once the regulation is set in force.

The distance between the city pair airports is 336 kilometers or 181 nautical miles. The flight is operated four times daily or 28 flights per one week. At the time of this research, the route is operated by one airline with no competition. Helsinki is the capital of Finland whereas Kuopio is the regional center of Northern Savonia. The flight between Helsinki and Kuopio is the only one operated to Northern Savonia from Helsinki and therefore it serves the whole region. However, it could be argued that its catchment area of Kuopio airport is much larger, perhaps even the greater Savonia region.

The fuel supplier in this research is a Finnish oil refining company Neste Oy. Neste is a fuel supplier to various industries, aviation included. Notably, Neste is not the only jet fuel supplier at Helsinki airport, but they specialize in sustainable aviation fuels which is why the company was selected for the research (Neste 2024). However, it must be noted that Neste is not the only possible SAF provider in Helsinki (Finavia 2024). Understanding the features of Neste’s sustainable aviation fuel helps to understand the overall impact of sustainable fuels.

The ReFuelEU aviation initiative was adopted into the EU legislation as a regulation in 2023 by the European Commission. It is part of European Unions “Fit for 55” legislation scheme which aims to reduce emissions in various industries in the Union. The regulation introduces an obligation on fuel suppliers to blend a growing share of sustainable aviation fuel to the fuel provided at airports in the European Union (European Council 2023). The regulation will commence by mandating 2% SAF ratio with kerosene in 2025 and continue to grow to 5% in 2030 and further into the future. The objective of the regulation is to reach the EU’s 2030 climate targets and potentially reduce carbon emissions by two thirds by 2050 compared to “no action” scenario (European Council 2023).

1.3 Research Question

The objective of this thesis is to understand the impact of ReFuelEU Aviation initiative to a selected domestic flight route in Finland. The topic is approached from two different angles: what will be the positive environmental benefits and how will the initiative impact operational costs and more specifically the fuel costs. In addition, it is important to gather a comprehensive understanding of what the EU’s initiative will mandate for the airlines. The aim is to have an estimate of these calculations for future use, and to provide a study that can be applied and referenced to other domestic flight routes with similar parameters. To specify the problem and purpose of the study, a research question must be determined. Furthermore, to support the main research and to answer the main research question, sub research questions are defined.

The main research question of this thesis is:

1. What is the impact of the ReFuelEU Aviation initiative to a selected regional flight route?

To support the main research question and to achieve the desired result, the following five sub research questions are studied:

1.1 What does the EU's initiative entail?
1.2 What are the current emissions and fuel costs on this route?
1.3 What is the total fuel consumption on this route?
1.4 How do the emissions of SAF compare to kerosene?
1.5 What is the cost difference between SAF and kerosene?

The nature of this study requires specific figures and estimates to partially answer sub research questions. Calculating emissions and costs to answer sub questions 1.3, 1.4 and 1.5 are based on concrete figures that remain constant but in some instances the figures are dynamic. For example, the cost of fuel is fluctuating, and it is depended on various factors like overall demand and the current price of raw materials. On the other hand, the emissions from kerosene and SAF remain constant and are therefore directly applicable.

The sub research questions 1.1 and 1.2 are exiting facts that are gathered during this research. The content of the ReFuelEU regulation will create a framework for this study where the data from the current emissions and costs serve as a baseline. Together, they will create a matrix where the changes mandated by the initiative are reflected gradually.

1.4 Scope of the Research

To provide a clear and comprehensive result, it is vital to define the scope of a research. Since this topic is strongly related to sustainability, it should be noted that the focus of this study is on environmental sustainability. This excludes social and governmental aspects from the scope. The environmental impact is assessed only considering scope 1 or in other words direct emissions produced during the operation. This excludes the scopes 2 & 3 or indirect emissions in upper and lower streams from this research.

Since aviation emissions are usually divided to passenger and cargo operation when calculating them, it is beneficial to define the topic. In this study, the objective is to focus passenger traffic on the selected route between Helsinki and Kuopio. This indicates that the methods to calculate emissions from passenger traffic are applied in this research. However, the selected method includes the total weight and fuel burn of the aircraft which might in some instances include belly freight of the aircraft. Moreover, the aim of this study is to calculate emissions only based on the total fuel burn and provide results that indicate the emissions caused for the airline. Emissions are not calculated based on a per passenger estimate, but more on a holistic level that can be used in future estimates.

Aviation operations emit different particles and water vapor into the air, ground, and water. In addition, noise pollution can be considered as a side effect from aviation. However, this study fill focus only to the air pollutants produced during operation. The topic in this thesis is related to the SAF mandate and therefore the scope is limited to the benefits gained exclusively from SAF usage. This means that other toxins and emissions released to the environment during flight or ground operations are not considered since sustainable aviation fuels are mainly used to reduce carbon dioxide emissions. Consequently, the objective is to understand specifically the CO2 emissions and compare the results between SAF and kerosene.

2 The Theoretical Framework

The objective of the theoretical framework in this thesis is to create an understanding of the current situation in the field of aviation and its sustainable development. Materials used for the theoretical framework are combined from previous studies and official sources from organizations relevant for this research.

The negative environmental impact and methods to mitigate it in the aviation industry are important understand for context to this research. The theoretical framework will discuss sustainable aviation fuels and their potential for the industry. The objective is to understand the environmental benefits of sustainable aviation fuels and their economic performance. In addition, the scopes of emissions are discussed due to the limitations of this study. Moreover, this section will gather data on the carbon emission calculations and identify the suitable method that can be used later in this research.

Introduction of the ReFuelEU Aviation mandate for sustainable aviation fuel usage in the European Union is additionally included to the theory which will ultimately create the framework for the thesis work. Researching and analyzing the content of the regulation is done as a part of secondary research.

2.1 Definition of Carbon Emissions in Scopes

Carbon emissions can be divided into direct and indirect emissions. The emissions produced during the different stages of a product’s or a service’s life cycle determine the scopes. The scopes can be divided to three main categories which enable carbon accounting in different desired points of the value chain. For the purpose of this study, it is important to outline these emissions since the extent of this study is limited to direct emissions or scope 1.

Scope 1 defines the direct emissions of a company that are from sources owned and controlled by the company. This means that emissions released to the atmosphere as a direct result of a company’s activities are counted as scope 1 emissions. All fuels used by the company that produce carbon or other GHG emissions are included in scope 1 (PlanA 2024). From an airline’s perspective, scope 1 emissions include kerosene combustion and its exhausts, but also all emissions produced from other facilities controlled by it. Usually, scope 1 emissions are the minimum requirement in carbon accounting.

Scope 2 emissions are usually limited to emissions derived from purchased energy. Scope 2 emissions are counted as indirect emissions as electricity is consumed by the end-user. All emissions released from the consumption of purchased electricity, heating, cooling, and airconditioning are included in scope 2 (PlanA 2024). For airlines, scope two is all the electricity purchased to power the facilities owned by them.

Scope 3 covers all other indirect emissions. These emissions are from the upper and lower streams in the value chain which are not owned by the reporting company. In other words, scope 3 emissions are not produced by the company itself but rather the suppliers and subcontractors in the upstream and low stream (PlanA 2024). The upper and lower streams include inter alia the acquiring of raw materials, production, transportation, utilization and disposing. Therefore, Scope 3 emissions include all sources not within the scope of 1 and 2 boundaries. For airlines and more specifically the fuel question, consuming the fuel is a direct emission of the airline, whereas producing the fuel is seen as scope 3.

2.2 Emissions from the Aviation Industry

It is estimated that the total contribution of aviation to global greenhouse gas emissions is approximately 2.4% or 918 million metric tonnes of carbon dioxide from fossil fuel use. Aviation is a continuously growing industry, and its emissions are expected to triple by the year 2050 if no measures to decrease emissions are implemented (Craver, Zhang & Rutheford 2018, 1). Hence, aviation industry must develop and apply measures to decrease emissions and accommodate growth simultaneously. Most likely, the decarbonization of aviation will be a combination of different methods like technological development, improvements in operations and infrastructure, sustainable aviation fuels and carbon offsetting and.

Emissions from aviation are a significant contributor to climate change. A study conducted by Craver, Zhang and Rutheford found that share of passenger operations globally was 747 million metric tonnes of CO_2 in 2018 or 81% of the total (2018, 4). It could be determined that most of the aviation emissions are caused from long haul or medium haul flights. Yet, the share of regional air travel in the total CO_2 emissions from aviation was approximately 5% (2018, 4). It could be argued that regional air travel is perhaps the hardest to justify since it could be replaced with alternative transportation methods with lower carbon intensity.

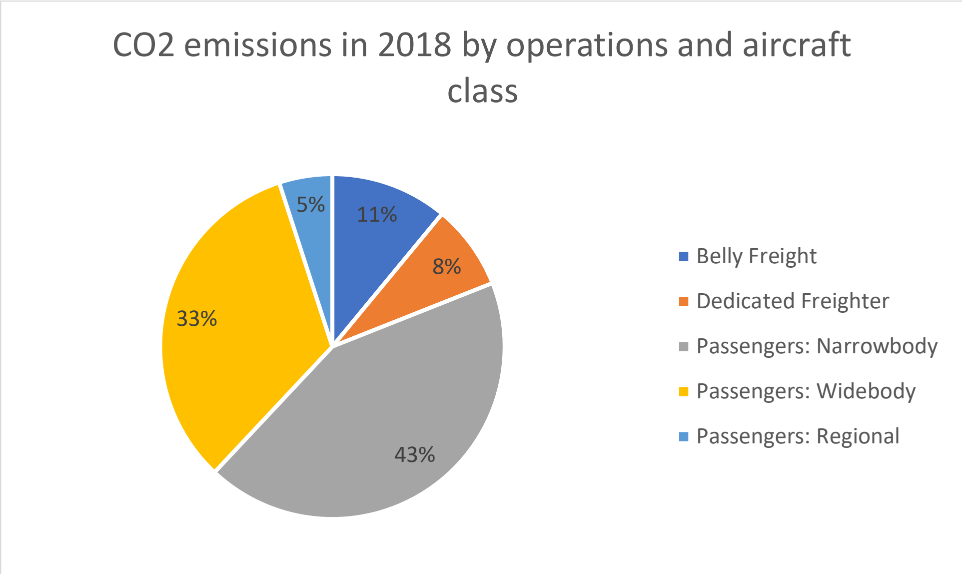

Figure 1. CO2 emissions in 2018 by operations and aircraft class (adapted from Craver, Zhang and Rutheford 2018, 4).

Direct emissions from aircraft are generated from fossil fuel combustion in the engines. These emissions are comparable to any other emissions derived from fossil fuels; however, aviation emissions differ from others slightly since they are emitted mostly in higher altitudes (ICAO 2024). Kerosene is a common jet fuel used in commercial aviation and it is used as reference in this study. Since kerosene is a fossil fuel, its combustion emits particles and gases to the atmosphere which ultimately contribute to climate change. Consumption of jet fuel is converted to CO2 and other non-CO2 gases like Sulphur, soot, and carbon monoxide (ICAO 2024). Therefore, the focus of decarbonizing the aviation industry relies heavily in sustainable aviation fuels and alternative propulsion methods.

2.3 Definition of SAF

Sustainable aviation fuel, or SAF for short, is a term used to describe sustainably sourced and produced jet fuel. Sustainable aviation fuel has considerably lower carbon emissions when compared to fossil derived conventional jet fuel (IATA 2024). SAF is produced typically from biological materials derived from plants or animals. However, it can also be produced from alternative non-biological sources. These so-called synthetic fuels or e-fuels are made from already manufactured materials and produced using renewable energy (IATA 2024).

SAF has approximately 80% lower life cycle CO2 emissions compared to kerosene. Since SAF is produced from biomass, the CO2 absorbed by it during the feedstock growth process is roughly equivalent to the CO2 emitted during the burning in combustion engines.

SAF has similar physical and chemical characteristics when compared to conventional fuels and it can be safely mixed with kerosene (IATA 2024). Blending SAF and kerosene together is currently a general method since SAF is not yet used with a 100% ratio. However, the applicable ratio of kerosene and SAF depends on the aircraft size and its engines. It is expected that SAF can be utilized with 100% ratio by the year 2030 (EASA 2024). Yet, the usage of SAF blend does not require any modifications to the engines or fuel supply infrastructure. Therefore, SAF is considered a drop-in solution since it can be implemented without adaptations to current air traffic operations.

Sustainable aviation fuels are widely accepted solution to decarbonize aviation industry since other technologies like electricity and hydrogen propulsions are still in early development phases. However, currently the supply of SAF is very limited and its price premium is high compared to conventional jet fuels. The current maximum production capacity of SAF in the EU is approximately 0.24 million tonnes. In comparison, the total jet fuel consumption in year 2022 was 61.6 million tonnes. The mandate of European Union requires the usage of 6% SAF blend by the year 2030 which would translate to demand of approximately 46 million tonnes (EASA 2024; Knoema 2022).

2.3.1 Environmental Benefits

Since alternative propulsion methods like hydrogen and electricity are still years or even decades away from being viable for commercial use, it is likely that SAF will be the primary solution to decarbonize the aviation industry. As mentioned before, SAF can have up to 80% lower lifecycle CO2 emissions compared to jet fuel (IATA 2024). However, the CO2 emissions depend on the percentage of each component when SAF is blended with kerosene. Notably, the emissions reductions gained from SAF can be reduced from the Scope 1 CO2 intensity of a flight in accordance with the environmental attributes for the quantity of SAF used (IATA 2024).

The emissions reductions are achieved mainly during the production phase since the emissions are comparable to kerosene from engine exhaust (IATA 2024). Hence, it is important to focus on the emissions produced during the production phase of SAF. Notably, the emissions vary remarkably between the different pathways of production and the raw materials. Since the scope of this research is the domestic air traffic in Finland, the most viable SAF provider is Neste Oy. Therefore, the focus of this study is on HEFA-SPK method which Neste uses to produce SAF from bio-oils, animal fat and vegetable oils (Neste 2024). HEFA stands for Hydro processed Esters and Fatty Acids.

The GHG emissions of fuels are provided in terms of gCO_2e/MJ, which can be compared to the relevant baseline emissions from fossil-based jet fuel in order to calculate the overall GHG emissions reduction (EASA 2024). The general reference value for conventional jet fuel is 89 g

CO_2e/MJ. In comparison the same value for SAF ranges between 13.9-60 g CO_2e/MJ depending on the pathway of production (Franke, Moshammer, Shehab & Zondervan 2023, 9).

In a study conducted by Magalhães, Ferreira, Rocha and Silva it was found that the lowest value of SAF produced through the HEFA-SPK method was 11.8 g CO_2e/MJ (2023, 6). In the lowest value, the feedstock that was used to produce the fuel was used cooking oil. The research used Life Cycle Assessment to determine the emission factor from the total lifespan of the fuel. However, the results varied remarkably depending on the feedstock that was used to produce the fuel. The highest emission factor of 52.1 g CO_2e/MJ was reached when canola was used as feedstock (Magalhães et al. 2023, 6).

2.3.2 Cost of SAF

Fuel cost comprises a considerable part of an airline's cost structure. The share of fuel can be up to 20-30% of the total costs of an airline (Henderson, Martins & Perez 2012, 4). Therefore, changes in fuel prices have a remarkable effect on airline's operational costs and profit margins. The relatively high price of SAF poses challenges for airlines as pressures to reduce carbon emissions increase. For the purpose of this study, it is important to review the price of SAF to gain understanding of the current market situation. However, the price of fuels fluctuates and receiving accurate data from the supplier is vital for a reliable result.

According to IATA, the price of SAF is minimum two and a half times higher compared to conventional jet fuels. In 2022, the average price of SAF was USD 2400 or EUR 2239 per metric ton and kerosene a mere USD 1090 or EUR 1005 per metric ton (IATA 2023). However, according to some estimates the price of SAF could be even three to four times higher depending on the supplier.

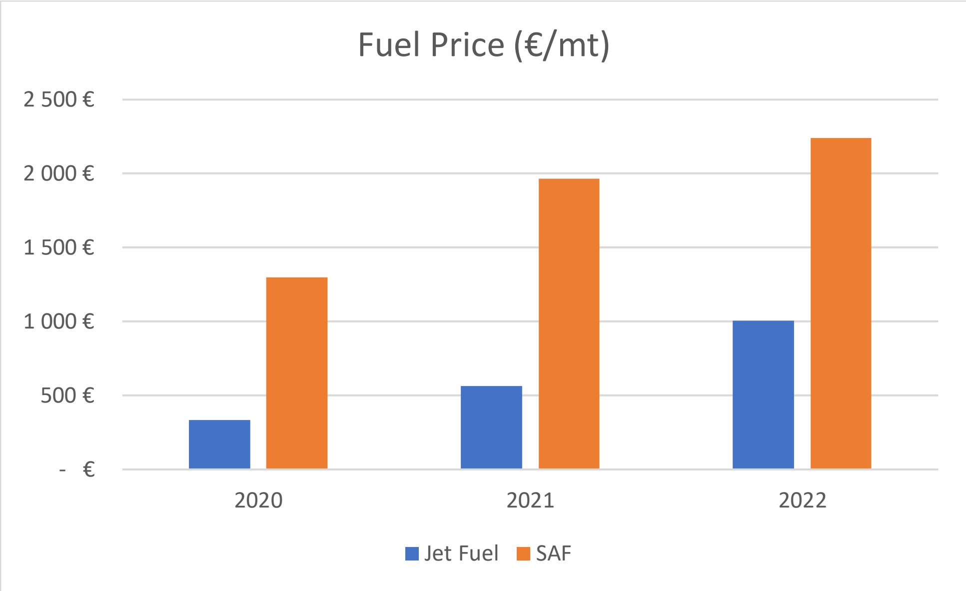

Figure 2. IATA Jet Fuel Price (adapted from IATA 2023)

Since the development and production of SAF is in its early stages, it could be assumed that the price will decrease overtime as the technology and market mature. The demand of SAF will increase which will translate to lower prices and increase in supply. The World Economic Forum estimates the price of SAF to drop 22% by 2050. The estimate is based on the price development of hydrogen, which is used in the production of SAF, and it is suggested that the feedstock price would stay the same (World Economic Forum 2020). However, a study conducted by the European Commission suggests that the price to produce SAF using the HEFA-SPK pathway would stagnate after 2035 and would not decrease after (image 1). The study indicates that the price for SAF would not be competitive against fossil jet fuels through any of the current pathways. Understanding the price of production is crucial since it will naturally affect the ultimate energy prices for airlines.

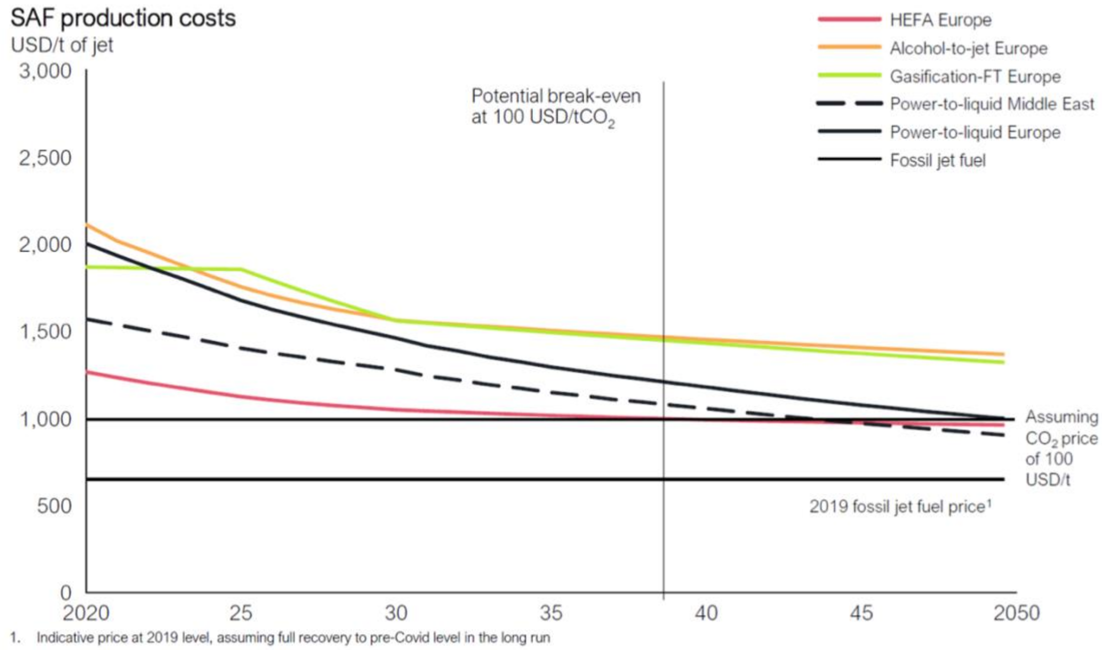

Image 1. SAF production costs (European Commission 2021, 26)

Previous study of European low-cost carriers' fuel costs forecasts the estimated price for SAF in the years 2023-2026 to be approximately 2500€ / mt. According to the study, the trend of price development is decreasing to 2000€ / mt in years 2027-2028 and again to 1500€ / mt in 2029-2030 (Sullastres Casals 2023, 57). In addition, the study found that an optimal usage of 50% SAF would cause an increase of 15% to operational costs during 2023-2026 assuming the share of fuel is 30%. Consequently, in one scenario proposed by the study, the price of 20% blended SAF would be lower in 2030 compared to 2023 (Sullastres Casals 2023, 31). Moreover, the study takes into consideration the benefit of costs accumulated from CO2 emissions, which is a valuable consideration when the cost of SAF is discussed. The price premium of SAF might decrease when it is proportioned to the carbon allowances and their price development.

2.4 Previous Research on SAF Implementation

According to previous research conducted by Sustainable Aero Lab (2024), the cost of SAF implementation will depend on the price premium of sustainable aviation fuels. In the study, the fuel price was incorporated to operational costs. Four scenarios were created with each demonstrating the price premium of SAF at 50%, 100%, 150%, and 200%. The most remarkable rise in operational costs was found when SAF was assumed 200% more expensive than conventional jet fuel and its ratio was 30%. In this instance, it resulted in an increase of 12% in operational costs. Even with 20% ratio the increase in operational cost was 8%.

A more optimistic scenario with the assumption of 50% price premium of SAF found only minor increases between 1-3% to operational costs with the ratio of 10, 20, and 30 percent. yet, a more realistic approach is perhaps the assumption of 100 and 150 percent price premium. With a 30% ratio, the scenario of 150% price premium would results in 9% increase to operational costs. The equivalent was found only to be 6% or at an acceptable level (Sustainable Aero lab 2024).

Another study conducted by équilibre des energies, found that by the end of implementation of ReFuelEU regulation the CO2 emissions could be cut by 40%. However, this study considered the whole life cycle emissions of SAF rather than direct emissions. The study suggests that most of the SAF would have to be produced synthetically to require less biomass since the supply is limited (équilibre des energies 2023). In addition, it was hypothesized that emissions from aviation will be reduced by a combination of methods like new technologies, hydrogen propulsion, and improvements in operations (équilibre des energies 2023).

Engine combustion research conducted by Kroyan, Wojcieszyk, Kaario and Larmi found that SAF would have approximately 3% lower direct carbon dioxide emissions relative to conventional jet fuel (2022, 10). The study presented results in kilograms emitted per hour. In addition, it was found that SAF combustion leads to less soot and Sulphur emissions compared to kerosene (2022, 2) Notably, the study was conducted by testing fuel properties in a jet engine, whereas the context of this study is propeller turbine engines.

2.5 Calculation of Direct Carbon Emissions

Direct aviation emissions can be calculated by using the fuel-based methodology. This relatively simple method measures emissions according to fuel consumption during different phases of the flight and the carbon emission factor of a selected fuel. However, the monitoring of fuel consumption can be done by different methods depending on the available data. According to IATA, there are five different methods to calculate fuel burn (image 2.).

Method A is based on the fuel quantity in tanks after the completion of the fuel uplift for the flight under consideration and the subsequent flight. In other words, the amount of fuel in tanks after the flight is reduced from the same figure before the flight, and the uplift for the next flight is added (IATA 2024). In method B, the fuel measurement at block-on times of preceding flight is reduced from the block-on measurement of flight under consideration. Then the fuel uplift before the flight is added to receive the total fuel consumption (IATA 2024).

The block off / block on method measures the fuel quantities in tanks before and after the flight under consideration. The fuel at block-on after the flight is reduced from block-off value before the flight. Block-off refers to the point in time between the last door closed and the first engine on, and block-on time as a point in time between the last engine off and first door open (IATA 2024). Fuel uplift based method simply measures the amount of fuel that is fueled at one time. However, if the flight is not preceded by a fuel uplift, the fuel consumption must be allocated according to block hours. Allocating the fuel uplift according to block hours is done by multiplying the total block time by the average fuel burn ratio of a selected aircraft (IATA 2024).

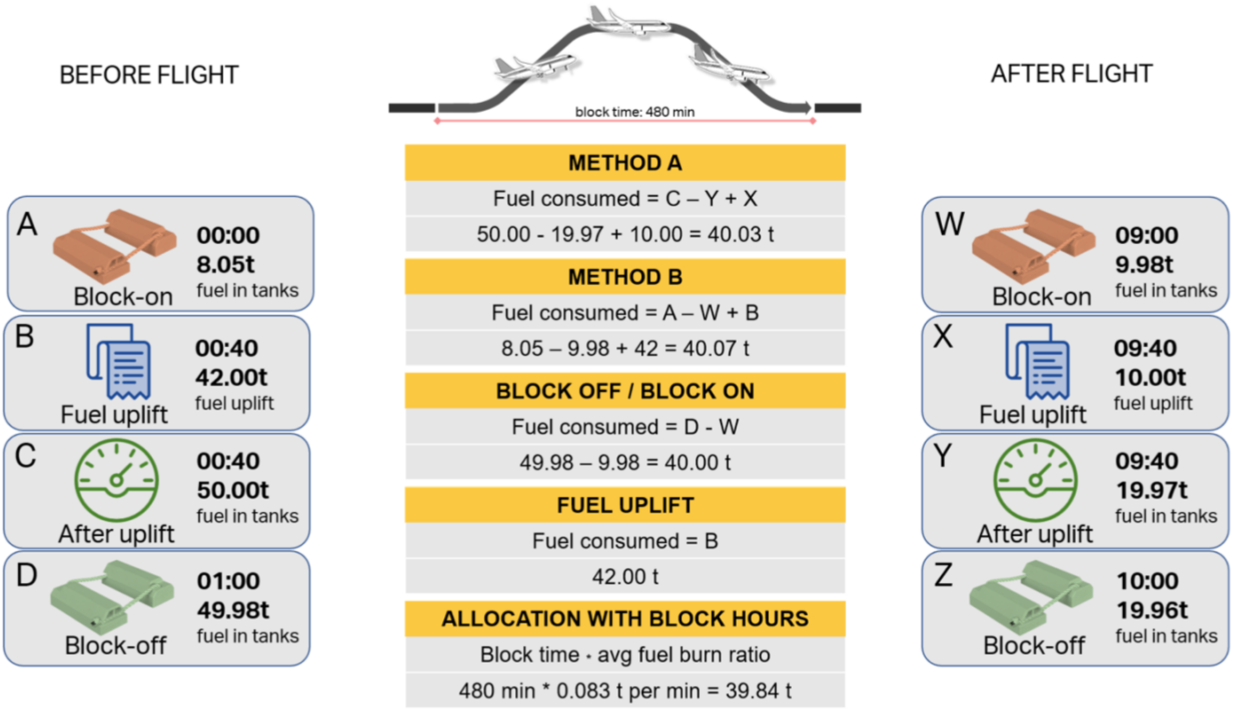

Image 2. Fuel use monitoring (IATA 2024).

After the total fuel burn is known, it is multiplied with 3.16 which is a constant representing the number of tonnes of CO2 produced per every tonne of Jet A or Jet A-1 fuel burned (IATA 2024). Notably, this method is not as accurate since it does not include the impact of the life cycle of the fuel or other pollutants like nitrogen oxides or water vapor (IACO 2018). However, this method provides a basic estimate of carbon emissions that can be projected to future estimates.

Fuel consumption (in tonnes) x Emission Factor (Kilograms of CO2 per tonne of fuel burned)

Formula 1. Emission factor (IATA 2024).

2.6 EU Sustainable Aviation Fuel Mandate

As part of Fit for 55 legislative package, the European Council has adopted the RefuelEU Aviation regulation which aims for reducing carbon emissions of aviation by two thirds by the year 2050.

The initiative is part of a larger scheme known as European Green Deal which aims for carbon neutrality by that same year. Fit for 55 has already included aviation to the EU ETS carbon emissions trading scheme. The objective of the ReFuelEU regulation is to increase demand and supply for sustainable aviation fuels and synthetically produced fuels, to ensure a sustainable air transportation market in the future (European Commission 2023). The initiative will obligate a progressively increasing minimum share of SAF blending with kerosene for all flights departing from the EU (Table 1.). The regulation will apply only to aircraft used for civil aviation in commercial air transport flights. For instance, this will exclude aircraft used in military, humanitarian, rescue, or any equivalent operation (European Council 2023).

The new regulation will apply in January 2024, however the articles which mandate SAF usage will be set in force in January 2025. The regulation will mandate a minimum 2% SAF supply together with kerosene during the first period. The requirement will increase over time gradually on five-year milestones to reach the end goal of 70% SAF in 2050 (European Council 2023).

Year of implementation	**% of SAF**	**% of kerosene**
2025	2%	98%
2030	6%	94%
2035	20%	80%
2040	34%	66%
2045	42%	58%
2050	70%	30%

Table 1. REFuelEU targets (adapted from European Commission 2023)

The regulation will oblige all airports in the EU to ensure their capability to store, supply and fuel sustainable aviation fuels. Consequently, the regulation will obligate fuel suppliers to ensure a minimum percentage of SAF in all the fuel made available for air operators from 2025 onwards. The mandate will extend to synthetic fuels in 2030. In addition, fuel suppliers must ensure that the fuels meet 70% of the Renewable Energy Directive’s sustainability and emissions saving criteria (European Council 2023). Eligible sustainable aviation fuels and synthetic fuels include certified biofuels, renewable fuels of nonbiological origin and recycled carbon aviation fuels. Further, ReFuelEU initiative will prevent the so called “tankering” practice where airlines fuel more than required for the flight to minimize or remove the need to refuel at the destination all together (European Council 2023). This would become apparent in a situation where the price of SAF or other fuel vary significantly between origin and destination. Tankering means that an aircraft will carry more fuel than required which increases its emissions remarkably.

The ReFuelEU mandate is being implemented since SAF is considered to be one of the best alternatives in short- and medium-term to decarbonize aviation. However, the supply is currently extremely limited, and the price is significantly higher when compared to conventional jet fuels. Therefore, the objective is to increase the demand of SAF, and to promote its production and ultimately lower the price (European Council 2023). The objective of the regulation is to ensure a gradual and continuous demand for SAF which would lead to high sustainability potential and competitive prices. Moreover, harmonizing the regulatory framework for SAF usage should level the playfield for SAF availability and price in the Union.

EU regulations are directly applicable to the legislation of member states. Therefore, the ReFuelEU Aviation regulation applies as is and it does not have to be transported to the Finnish law in this instance (EU Monitor 2024). This ensures a uniform implementation of the law all over the European Union. European Commission will be responsible for monitoring the regulations implementation, and member state authorities must propose penalties for suppliers and airlines in case it is not followed. However, the penalties should adhere the to the criteria defined by the Commission (PACE 2023).

3 Research Methods

This chapter will discuss the research methods and strategy of this thesis. The research is a case study because it examines one selected flight route. This thesis is research oriented, and it uses qualitative research methods to collect and analyze data. In research-oriented thesis, it is vital to identify whether the research is qualitative, quantitative, or possibly both by nature. Qualitative approach was selected because the topic requires specific answers from experts, and data which doesn't rely on numerical or statistical data.

This chapter will define the research methods used and justify the reason they have been selected. The data is collected through semi-structured interviews and secondary research. Moreover, this chapter will define the data analysis methods and the overall design of the research.

3.1 Definition of Qualitative and Quantitative Research Methods

Research methods can be divided to qualitative and quantitative methods. Selecting the research method between qualitative and quantitative depends on the nature of the study in question. These methods can be used separately or together to support each other. It is important to identify the correct data collection tool to achieve the desired result. Qualitative and quantitative research methods have different approaches to find patterns in the collected data that supports existing theories but can additionally conclude new ones. Usually, qualitative studies are more subjective and structured whereas qualitative is more objective and measurable (University of Southern California 2024).

Quantitative research aims to understand phenomena through analyzing numerical and statistical data. Quantitative research focuses on gathering numerical data and generalizing it across groups of people or to explain a particular phenomenon (University of Southern California 2024). The method is usually used to identify patterns and averages, or to make predictions for the future. Quantitative research can be descriptive, correlational, or experimental (Scribbr 2020). The benefits of quantitative research are its replicability, possibility to compare results directly, and hypothesis testing. Its disadvantages could be considered narrow focus of the study, structural bias, and lack of context (Scribbr 2020).

Qualitative research on the contrary collects and analyses non-numerical data to understand concepts, opinions, and experiences (Scribbr 2020). The nature of data gathered from qualitative research is usually more in-depth and detailed. Qualitative research is seen as the opposite of quantitative research where the research focuses on numerical data. The methods used in qualitative studies are commonly observations, interviews, surveys or focus groups. The benefits of qualitative research are seen as its flexibility, meaningfulness, and possibility of discovering new ideas. Its disadvantage is usually the unreliability due to its uncontrolled factors, In addition, subjectivity and limited generalizability (Scribbr 2020).

This thesis will combine two research methods: secondary research and semi-structured interviews. In this research, secondary research is used to gather data on the ReFuelEU Aviation regulation to form a framework to be used in comparison. The data from the operating airline and fuel supplier is gathered from semi-structured interviews. Notably, a semi-structured interview as a research method could be qualitative in nature. However, the data is organized in numerical way, or by using quantitative method. Despite this, the research is qualitative.

3.1.1 Secondary Research

Secondary research uses previously gathered data from peer-reviewed papers, meta-analyses, or government or private sector databases. When research is conducted by using data that already exists, it’s referred as secondary research. Secondary research can be qualitative or quantitative depending on the data (Scribbr 2023). In this thesis, the secondary research is used to form the theoretical framework (literature review) and to gather the necessary data for the EU regulatory framework. Literature review is a necessary part of the thesis since background information and previous studies create the base for new research. On the other hand, case study is a detailed study of a topic which is required in this instance to understand the framework. Conducting secondary research requires unbiased data that is collected from reliable sources.

3.1.2 Semi-structured Interview

Semi-structured interview is a data collection method where interviewees are asked predetermined questions in a thematic framework. The interviews are usually qualitative in nature, and it is often used as an exploratory tool (Scribbr 2022). Semi-structured interviews are mix of structured and unstructured interviews. The interviewer knows the questions they will ask but the questions are not set in order or in phrasing (Scribbr 2022). Semi-structured interviews allow for detailed data gathering and it is flexible because of the combining of elements from structured and unstructured interviews. However, the flexibility can result in low validity of the gathered data and results, and the comparison of responses might be difficult.

Semi-structured interviews are selected as the research method for this study because the information of fuel prices and their emissions are not all publicly available. The cost of fuels fluctuates, and it is highly dependent on the supplier. Therefore, the data must be gathered directly from the supplier, and a semi-structured interview is most effective tool in this instance. In addition, data of SAF emissions must be gathered from the supplier since it is not publicly available, and it depends on the production pathway. Data is required from experts in the field to ensure a more reliable result.

3.2 Data Analysis

The data analysis method in this study follows a realistic approach where the objective is to understand the content of the data precisely and what can be concluded about the topic of the research. This research will use qualitative content analysis method to analyze data from the interviews. Qualitative content analysis can be applied when analyzing written text, interviews, recordings, or sound (Kallinen & Kinnunen 2024). Qualitative content analysis differs from traditional content analysis. The objective of qualitative content analysis is not to find repeating patterns but identify details (Kallinen & Kinnunen 2024).

The collected data must be refined to a theoretical form to facilitate the analyzing process. The semi-structured interviews were recorded, and additional notes were taken. In this research, the interviews are transcribed, and the data is coded to identify the relevant points for this research. The written material is analyzed several times to ensure precise understanding of the discourse. The refined data is inserted to a table (table 3.) to highlight the relevant points required for the creation of hypotheses. Notably, a portion of the questions asked during the interview are not displayed in the table due to their irrelevance for the study.

3.3 Research Design and Strategy

The objective of this study is to gain an understanding of the economic and environmental impact of ReFuelEU Aviation regulation. More specifically, the effect of the regulation is studied by comparing the costs and CO2 emissions. The literature review in this thesis gathered existing literature, studies, internet sources and EU legislation materials to create a holistic understanding of the topic. After this, the baseline scenario is formed based on the data gathered from semi-structured interviews and secondary research. The baseline situation data of this study should cover both the current CO2 emissions and fuel costs.

Data concerning the total fuel consumption and fuel costs will be collected from the interview with the operating airline representative. The current CO2 emissions will be determined based on the total fuel consumption data and multiplying it with the emission factor of kerosene. The fuel calculation method is applied if the fuel burn data is not directly available.

Data of current price and the price development estimates of SAF will be gathered from an interview with Neste representative. If there is no data on price development estimates, the current value will be used as a reference to the future models. In addition, the objective of the interview with Neste is to gather data on the CO2 emissions of SAF and understand how it compares to kerosene. Notably, it is essential to understand if the CO2 emission reduction rights are offered for the airline to use in their scope 1, or can the reductions be reduced only from scope 3.

Secondary research will be used to research and form the ReFuelEU Aviation regulatory framework. By using this framework, the progressively increasing SAF mandates can be referenced to the baseline scenario and create future scenarios for years 2025, 2030, 2035, 2040, 2045 and 2050. The objective is to investigate how the increasing amount of SAF will affect the CO2 emissions over the years when compared to the baseline scenario. Similarly, the development of fuel costs is compared to the baseline scenario. The environmental and economic analyses are divided to two separate sections.

	BASELINE SCENARIO	ReFuelEU Aviation Regulation					
	2024	2025	2030	2035	2040	2045	2050
CO2 EMISSIONS							
FUEL COSTS							

Table 2. Research Framework

4 Results and Data Analysis

This research included two semi-structured interviews with representatives from SAF provider company Neste Oy and the operating airline. The interviews were held remotely on 18.3.2024 and 21.3.2024 via Teams platform. The interviews were recorded, and eventually analyzed by using qualitative content analysis method. Participants were informed that the interviews would be recorded, and that the final research paper would be public. In addition, the participants were informed that the data would be used exclusively for this research and that the interview recordings would be deleted after the analysis process would be complete. The participants had an option whether to stay anonymous or include the company name in this research. Notably, the interviewees were informed in advance about the content of the research and their consents were confirmed.

The two recordings were analyzed, and the refined data is displayed and elaborated in this chapter. Tables 3. and 4. depict the refined results gathered from the recordings. Notably, part of data was received after via email since they were not directly available during the interview.

4.1 Semi-Structured Interview with Neste Oy

The objective of the interview with Neste was to understand the direct carbon emissions of SAF and its cost compared to kerosene. The data was collected from a semi-structured interview with a representative from Neste Oy. It should be noted that some of the data was provided after the interview via email, since some information was not at hand during the discussion. The questions were divided to two themes: environmental and economic and they are presented in table 3. Notably, the table only presents the answers that are relevant for the research. The answers to following questions are analyzed separately one by one.

The first questions were structured in a way so that data of the environmental aspects of Neste's SAF could be gathered. The interview with Neste reveals the production pathway to produce SAF. In this instance the method is called HEFA or Hydro processed Esters and Fatty Acids. The method is developed and patented by Neste, but it is comparable to similar methods used around the world. Neste has altogether three production facilities to produce SAF around the world. The raw materials to produce SAF are animal fats derived for example from offal and used cooking oils.

According to Neste, the emission factor of SAF produced by them is 0. This indicates that the direct CO2 emissions from the combustion are 0. This applies to other GHG emissions which are however not included in the study. Therefore, the emission factor of SAF which is applied to this case is 0. In addition, the objective of the interview was to understand to which scope the emissions reductions can be allocated from the airline's perspective. The answer was that the emissions reductions for airline are in scope 1 since they are derived from owned or operated assets.

The second part of the interview presented questions related to the cost of SAF. The SAF produced by Neste is 3-4 times more expensive than conventional kerosene. Therefore, it is assumed that SAF will cost 3,5 times more than conventional jet fuel. According to the interview, the price of SAF is not expected to decrease in the future due to the expected increase in demand and rare supply of the raw materials. Notably, it was emphasized in the interview that the cost of EU ETS carbon allowances will balance the overall price difference between kerosene and SAF. Hence, it should be noted that the approach to examine cost difference between the fuels should take into consideration the costs generated from carbon emissions. The final results should be examined critically since the price difference does not reflect the market situation and its relevance to the total price of energy.

Notably, this interview did not collect data on the current price of kerosene. The price of kerosene was excluded from the interview because of the uncertainty about the fuel supplier of operating airline. Therefore, the exact estimate of jet fuel price from Neste would have been inaccurate in this study. However, the price of kerosene is similar among suppliers and the market's price average can be reflected to the cost difference with SAF. The data that is required from the operating airline is the current fuel costs regardless of the supplier. It could be assumed that the SAF supplier is most probably Neste and the price difference between jet fuel and SAF is the estimate received from Neste, 3-4 times higher.

Question	**Answer**
What is the production method used to produce SAF?	HEFA-SPK.
What are the main raw materials used to produce SAF?	Animal fats and used cooking oil.
Does Neste's SAF have an emission factor comparable to kerosene (3.16)?	0
What are the direct CO2 emissions of SAF caused form combustion?	0

Does an airline benefit from the emissions reductions in scope 1 or scope 3?	Scope 1.
How many times more expensive SAF is compared to kerosene?	3-4
How do you expect the price of SAF to develop in the future?	The price won't decrease significantly in the future.

Table 3. Answers to Semi-structured interview with Neste Oy.

4.2 Semi-Structured Interview with the Operating Airline

Similarly to the previous interview, the questions were divided to environmental and economic themes. The analyzed answers are presented in table 4. It should be noted that some of the data was provided after the interview via email, since some information was not at hand during the discussion. The objective of the interview with the representative from the operating airline was to understand the total fuel consumption, or alternatively the required data so that the fuel consumption could be calculated by using the fuel burn calculation methods. It was additionally beneficial to gather data on the number of daily flights to provide estimates for wider timespans. In addition, the goal was to understand whether SAF is already used on the route and if that should be taken into consideration when forming the baseline scenario. Moreover, the creating the baseline scenario requires data on the current fuel price and provider.

The aircraft which is operated on this route is ATR 72-500. It was estimated that this aircraft type is used on almost every operation so any assumptions could be based on this aircraft model. The block time of this flight is approximately 60 minutes. As mentioned before, the block time refers to the time between when aircraft leaves the gate at its origin and arrives to the gate at the destination. It is important to understand the fuel consumption of the whole block time which includes taxiing, take-off, cruising, and landing.

According to the interview, SAF is currently being purchased by the operating airline in some quantities. However, it cannot be traced to one specific operation. Therefore, the baseline scenario should assume that the current ratio of SAF is 0. The fuel provider is not specified, and it varies between the three different companies at Helsinki Airport.

The fuel burn is measured by using the block-on / block-off method. Fuel burn naturally varies between operations depending on the total load of the aircraft. However, an average was provided which can be used in this research and it eliminates the need to calculate fuel burn manually. The average fuel burn per one leg is 650 kg or 0,65 tonnes. Notably, the aircraft is usually fueled only at Helsinki when possible. Hence, tankering is practiced on this route apart from few irregular situations. According to the ReFuelEU Aviation regulation, tankering will be prohibited from 2025 onwards which indicates that the flight can carry the fuel required only for one leg.

Currently, there are four daily flights to Kuopio from Helsinki. The same aircraft returns to Helsinki without layovers in between. The flight is operated every day of the week with the same frequency. The total amount of weekly rotations is therefore 28 with the exception of some seasonal irregularities. The demand on this route is not expected to grow remarkably in the future and there is no need to increase flight frequencies. However, estimating demand as far into the future as 2050 is difficult and not reliable.

The price of the fuel is a crucial piece of data for this research. The operating airline was asked to provide data on the fuel prices based on the average of 2024, the same year where the baseline scenario is created. Fuel prices are dynamic and there can be remarkable fluctuation in prices depending on various internal and external factors. The fuel prices were different in Kuopio and Helsinki according to the interview. At Helsinki, the price of fuel per kg was 0,96€. In comparison, the price was slightly higher at 1,13€ per kilogram. Notably, the research should take the price difference into consideration since the EU regulation will deny tankering practice. Consequently, it could be assumed that fuel price is higher at the leg between Kuopio and Helsinki.

Question	**Answer**
Which aircraft is operated on the route?	ATR 72-500.
What is the total block time of this flight?	Approximately 60 minutes.
Who is the current fuel supplier?	Not defined.
Is SAF currently in use on this route?	Currently, SAF can’t be traced to a single flight.
How is fuel consumption monitored?	Fuel burn is monitored by using the block-on / block-off method.
What is the fuel burn per one block time?	On average, the fuel consumption is currently 650kg per on leg.

What has been the average fuel price in 2024?	In Helsinki the average price is 0,96€ / kg. In Kuopio, the average price is 1,13€ / kg.
Is tankering practiced on this route?	Yes, the flight is fueled currently only at Helsinki.
How many daily flights are operated to Kuopio?	4 daily flights.
Is the flight frequency expected to grow in the future?	Demand is not expected to increase in the future and therefore frequency will most likely stay the same.

Table 4. Answers to Semi-structured interview with the operating airline.

4.3 Baseline Scenario Formulation

The baseline scenario depicts the current CO2 emissions and fuel costs. The refined data from two previous interviews are combined to formulate it. The progressive increase of SAF blend is then reflected to the baseline in the discussion chapter. Creation of the baseline is a key part of this research since it is reflected to all reference years, and the calculations are formed on the baseline values. The baseline scenario values are directly received from the operating airline and fuel provider so the margin of error could be considered small.

The direct CO2 emissions can be calculated now once the total fuel burn is available. In this instance, the fuel burn was provided directly by the operating airline, and no separate fuel calculation methods were applied. The CO2 emissions are calculated by multiplying the total fuel burn per on leg by the emission factor of kerosene 3.16. The calculation is as follows.

Fuel consumption (in tonnes) x Emission Factor (Kilograms of CO2 per tonne of fuel burned)

0,650 tonnes x 3.16 = 2.054 tonnes / CO2

The fuel cost of the baseline is calculated based on the average fuel price in Helsinki in 2024 (Jan-Mar). Since the flight is currently being fueled only at Helsinki, it is beneficial to calculate fuel cost by using the value of fuel price in Helsinki. The total fuel cost per one leg is calculated by multiplying the total fuel burn by jet fuel price per kilogram. The calculation is as follows.

650kg x 0,96€ / kg = 624€ / one operation

The 2024 baseline scenario of CO_2 emissions is 2.054 tonnes per one leg. The fuel cost of one leg is approximately 624€. These values are utilized in the next chapter to present the future scenarios for years 2050-2050.

4.4 Reliability and Validity of the Research

The research method of this study was semi-structured interviews. Along with it, secondary research was used to research and create the framework. Normally, semi-structured interviews would require a minimum of five interviews with the same theme to ensure reliability. However, it could be argued that in the context of this study the data is not dependent on the number of interviewees. The data that was required for this study would not have changed if multiple representatives from the same company would have been interviewed. In other words, it could be assumed that the data collected from the two interviews with two different companies are reliable with little variable factors.

The data from the two recordings of different interviews was analyzed by transcribing them and combing through the data multiple times to identify relevant points. The possibility of misinterpretation of data and human error is possible, but it should not affect the validity of the results remarkably. Notably, a portion of the data was received after the interview via email, which should not affect the reliability significantly.

The reliability of secondary research is dependent on the quality of data gathered from it. In this research, the sources used to gather data on the regulatory framework were official European Union websites and papers. It could be assumed that the information on the official sites is reliable. Naturally, the validity of the results depends on the author’s personal interpretation of the data.

The fluctuation of fuel prices is an uncertainty factor in this study since it is hard to predict them in the future. Fuel prices depend on external factors which might change due to various reasons, like geopolitical tensions or the overall price of raw materials. However, it is safe to assume that the average price of fuel represents the current market situation well. Notably, the price of SAF is based solely on the estimate received from the interview with Neste. However, Neste might not be the only provider of SAF at the market in the future. It is therefore uncertain if SAF supplied by another provider would be more competitive compared to kerosene.

The objective of this study is to project current situation into the future. Therefore, a remarkable part of the research is based on averages generated from past data. This creates an unreliable factor since it does not take into consideration variables like seasonality and flight specific load and fuel burn. The fuel burn of a flight might change drastically between different operations and an average figure is only directional. In addition, the average values do not take irregularities in operations into consideration. However, it could be argued that specific metrics from each flight would not serve the purpose of this study which aims to provide an estimate for the next 25 years.

5 Future Scenarios and Discussion

This chapter will present the future scenarios of CO_2 emissions and fuel costs. The objective of this research is to provide an estimate for every year indicated in the ReFuelEU Aviation regulation. Based on the regulatory framework, each year is compared to the baseline scenario and the correlation of SAF price and carbon emissions is examined. In addition, this segment will provide an annual estimate for every reference year to underline the total CO_2 emissions and fuel costs. The results of CO_2 emissions are presented in figure 3. and the estimate of fuel cost development per one operation is displayed in figure 5.

This chapter will additionally discuss further the results and provide research suggestions for the future. The topic of this study is relatively new and therefore the need for further research exists. Even this exact case could be studied further in more detail and include topics that were limited from this thesis. In addition, the possible outcomes from the changes to operational costs and CO_2 emissions are discussed further.

5.1 Future Scenarios of CO2 Emissions

Assuming that the direct carbon emissions from SAF provided by Neste are zero, the baseline scenario emissions can be multiplied by the value which has excluded the percentage of SAF blend. For example, the value for the year 2025 was reached by multiplying the baseline CO_2 emissions by 0,98 which considers the predicted 2% SAF blend. The same method is applied to every year by adjusting the SAF percentage according to ReFuelEU Aviation regulation.

As mentioned before, the value for 2025 was received by multiplying the baseline scenario emissions by 0,98. For 2030, the baseline emissions were multiplied by 0,94, for 2035 by 0,80, for 2040 by 0,66, for 2045 by 0,58, and for 2050 by 0,30. Notably, it is assumed that the direct emissions from SAF are zero. However, the secondary research would suggest that SAF produced by using the HEFA-SPK method would produce direct emissions during combustion and the emission factor would not be zero. The difference in direct CO_2 emissions between SAF and kerosene is relatively insignificant according to the theoretical framework (see chapter 2.4). This contradiction could be explained by Neste’s unique production method or the assumption that the emissions would be completely compensated during the life cycle of the fuel which would result in zero emissions. Yet, the possibility of misinterpretation of data from semi-structured interview cannot be excluded either.

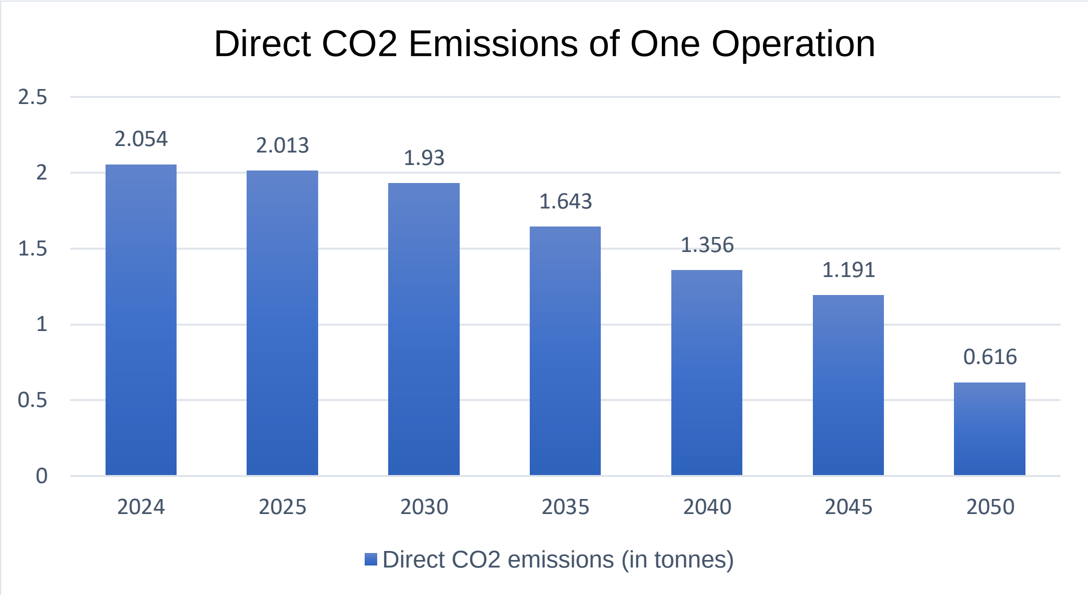

Figure. 3 Direct CO2 emissions estimate for years 2025-2050.

Notably, the CO2 emissions reductions are relatively small during the first five years of implementation. The first year of implementation will see a drop in CO2 emissions by only 0,041 tonnes. The decrease follows a similar trend until the year 2030. The difference between the baseline scenario in 2024 and 2030 is 0,124 tonnes or 6% of CO2. However, the fuel costs have risen already 15% from the baseline scenario (figure 4). In 2035, the emissions see a drop of 20% from the baseline.

The most remarkable change happens between 2045 and 2050 where there is a significant drop in CO2 emissions by 48%. The SAF mandate increases from 42% to 70% between 2045 and 2050. Consequently, the fuel price increases by 25,45% between these years (figure 4). It should be noted that currently the maximum limit of SAF blend with kerosene is 50%. However, according to some estimates 100% ratio will be passed by 2030. Yet, it should be noted that even with 42% SAF blend, the emissions can be nearly halved from the baseline scenario.

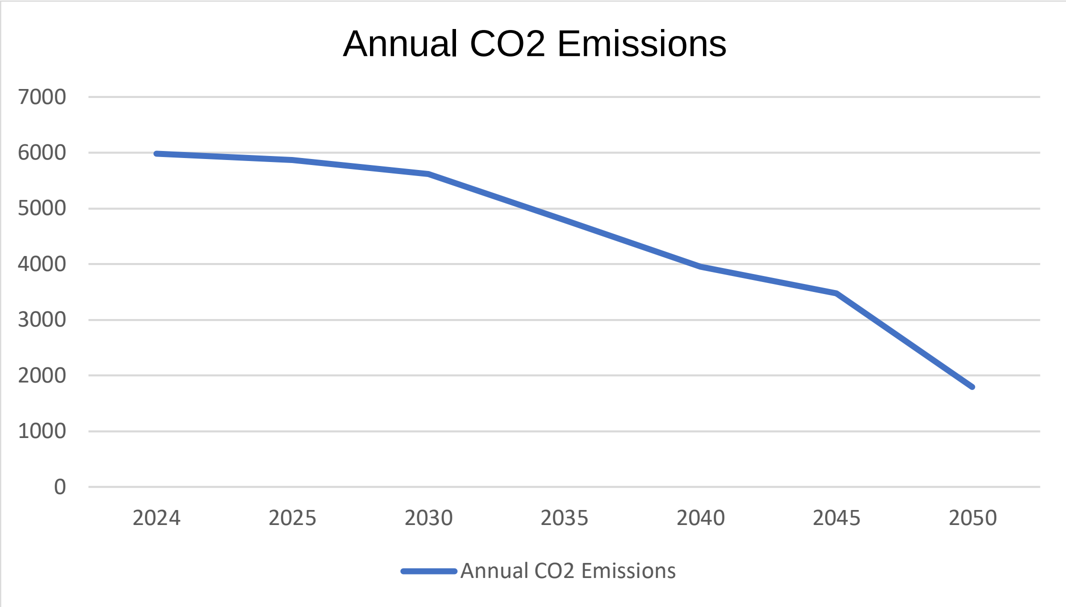

Figure 4. Annual CO2 emissions estimate for years 2025-2050.

Assuming that the amount of CO2 stays relatively same per every operation, and that the flight frequency is consistent every week of the year, the baseline scenario for annual direct CO2 emissions from the flight route between Kuopio and Helsinki is approximately 5981 tonnes. Naturally, the trend is decreasing and follows the pattern of a single operation. At the beginning of the implementation in 2025, the annual carbon emissions are a mere 5862 tonnes. The emissions drop below five thousand tonnes in 2035 when annual emissions are expected to hit 4785 tonnes. From there, the decline of emissions is more rapid as the figure for 2040 already suggests annual emissions of below four tonnes, or approximately 3948 tonnes. The total percentual difference between the baseline scenario in 2024 and the final year of the implementation is 70%, or precisely the amount of expected SAF blend ratio that year.

5.2 Future Scenarios of Fuel Costs

Fuel makes up one of the largest parts of an airline’s cost structure. Therefore, increase in fuel prices might have a remarkable impact to overall profitability. The value for each reference year was received my multiplying the percentual part which corresponds the amount of SAF in use at the time by 3.5. As mentioned before, the value 3.5 represents the price premium of SAF since it was discovered in the semi-structured interviews that SAF is approximately 3-4 times more expensive than conventional jet fuel.

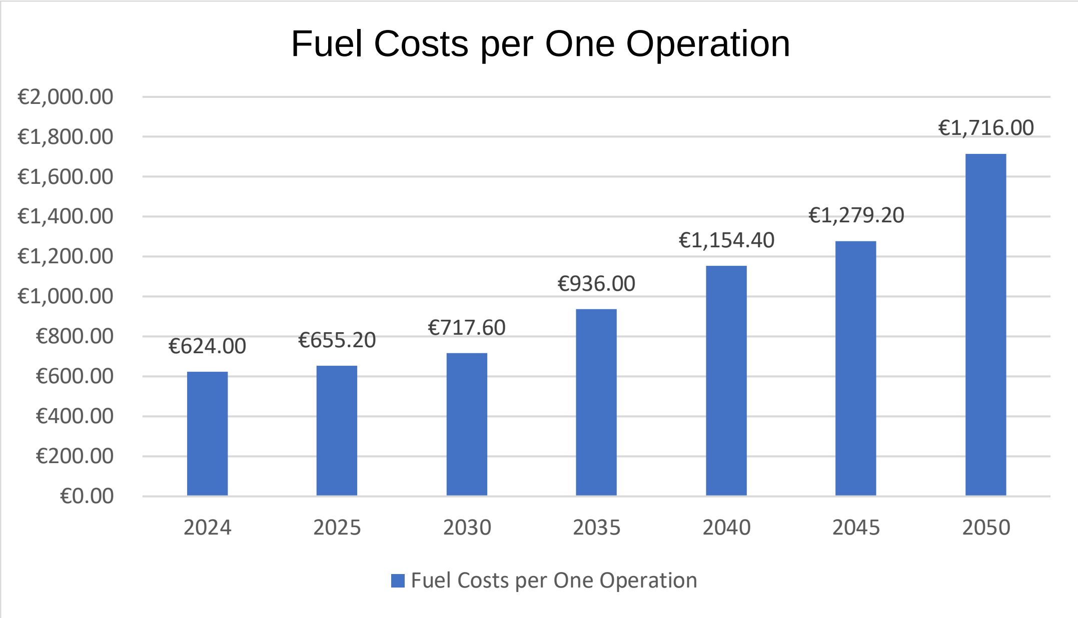

Figure 5. Fuel cost estimate for years 2025-2050.

The impact of ReFuelEU Aviation regulation is relatively small during the first five years of implementation. The first year of implementation indicates the fuel price to rise only approximately 30 euros from the baseline. After 2035, the fuel price starts to increase more drastically and in 2035 it has increased approximately 300 euros or by 50%. As mentioned before, in 2035, the CO2 emissions have dropped by 20% which is a remarkable change with a relatively small increase in fuel (figure 5). When comparing the beginning of the implementation to the end, the fuel cost has almost tripled and increased by 175%.

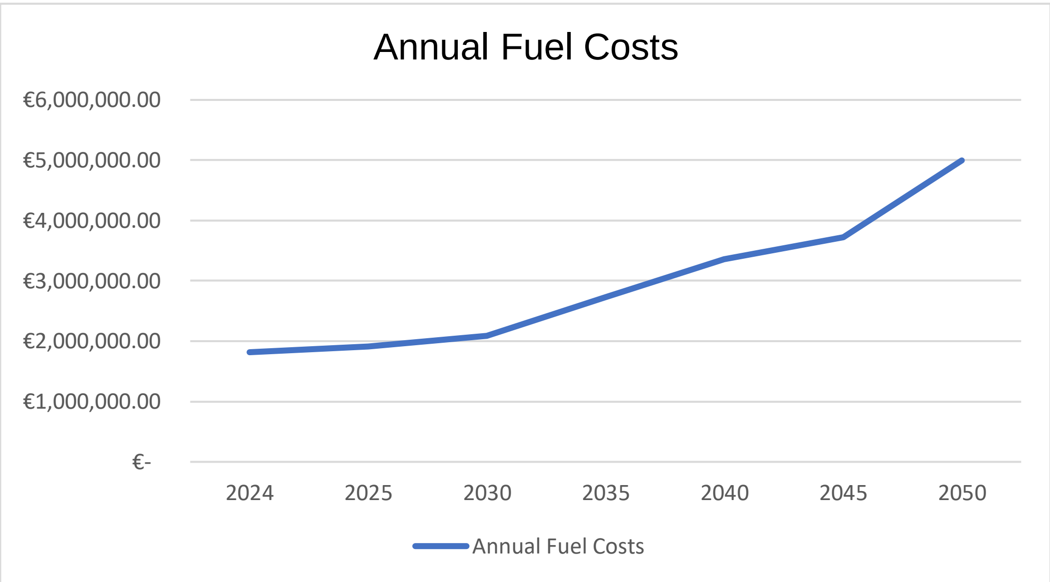

Figure 6. Annual fuel cost estimate for years 2025-2050

The reference scenario of annual fuel costs is approximately 1,8 million euros. The growth is naturally comparable to the trend of a single operation. In 2035, the fuel cost increase to 2,7 million as the SAF blend increases to 20 percent (figure 6). Another significant increase appears in 2045 when the price increases from 3,7 million euros to nearly five million euros (figure 6). This would have a significant impact to the total operational costs of this flight route. It is uncertain how and airline will accommodate such increase in fuel prices. The operating airline has the option to place surcharges for passengers to compensate the price difference which would increase the airfare. This could be a viable solution since currently there is no competition on the route. Optionally, the operational costs could be optimized to reduce costs. However, it is unlikely that operational costs have room for significant reductions since they are already optimized.

5.3 Future Scenarios Conclusion

The trend of CO2 emissions is naturally decreasing, and it follows the pattern of increasing SAF ratio. Similarly, the trend of fuel cost is increasing due to the higher price of SAF. These were both expected results based on the literature review which found similar results in previous research. Based on the data gathered from the semi-structured interviews, it could be assumed that the price of SAF will stay approximately the same as it is in the baseline scenario. Therefore, the increase in fuel cost is a probable scenario for all the referenced years. However, the fuel price should be compared to the price of EU ETS carbon allowances. The price of carbon allowances might compensate for the overall increase in fuel prices and justify the higher price of SAF. These results should be reflected to the total price of energy and carbon emissions.

Since the operating airline can claim the carbon emissions reductions in their scope 1 emissions, the results are promising. The operating airline’s direct emissions would be cut by 70% by 2050. This would be a remarkable drop in CO2 emissions. The result would not be total carbon neutrality however, the remaining 30% could be compensated by using various methods. Since fuel combustion is the main source of emissions for airlines, the SAF mandate would decrease them significantly, allowing airlines to accommodate growth. However, it is likely that the fuel costs will more than double during the implementation period. This must be addressed by the government since operational profitability might be difficult to reach with such increase to overall costs.

6 Conclusion

This study was successful since data could be gathered from actual stake holders related to the case. The fuel supplier and operating airline were both reached for interviews. Therefore, it could be argued that the data sources and results were relatively reliable. Despite this, much of the results were based on averages and the results were provided as average values as well. However, this research was able to provide a comprehensive result which could be projected to the future with relatively good accuracy. Notably, the regulation has not been completely implemented yet which leaves room for variables for the coming 25 years.

The results of this thesis are promising from the environmental perspective. The ReFuelEU appears to be an effective way to reduce the carbon footprint of commercial aviation in the European Union. It was found in this study that the SAF ratio is directly correlational to emissions reductions due to the emission factor being 0. In other words, the percentage of SAF can be reduced directly from the emissions. However, the implementation might be challenging at the beginning for fuel suppliers and airlines due to higher costs and scarcity of materials. It is unclear how the higher costs will be reflected to the consumer, but it is probable that the price of air fares will rise.

The contradiction between research results and theoretical background concerning the direct emissions of sustainable aviation fuels must be noted when examining the results. According to previous research, the benefits of SAF usage rely heavily on its emissions reductions during the whole life cycle rather than direct emissions. This leaves the question whether the data from Neste was unreliable or if the product can actually achieve zero direct emissions.

The success of implementing ReFuelEU Aviation regulation will depend on the supply of SAF. Currently, the supply of SAF is extremely limited and production is not at the required level to be able to produce the increasing amount mandated by the regulation. The scarcity of raw materials needed to produce sustainable aviation fuels makes it even more difficult to increase production in a short time frame. Notably, sustainable aviation fuels cannot be produced from virgin raw materials and waste derived sustainable raw materials are in limited supply. However, the development of synthetic e-fuel will most likely replace some of the supply, but their costly production could increase the prices even more. Consequently, it was not discussed in this research what are the protocols if SAF is not available by any means at the beginning of the implementation.

The scope of this study was relatively limited, and a more detailed study is recommendable. The scope was limited to examine only carbon emissions, but aviation has much broader environmental impacts. Other greenhouse gases were not included even though they might have equally harmful impact to the environment as carbon dioxide. However, it could be argued that the benefit of sustainable aviation fuels derives mainly from reduced carbon emissions and therefore it wasn't reasonable to include them in this study. Moreover, this study included emissions only in scope 1, but a truly transparent and accurate carbon accounting would require inclusion of all three scopes. Examining emissions from the complete lifecycle of fuels is a much more complex process.

Research on the correlation between EU ETS carbon allowance prices and the higher price of sustainable and synthetic aviation fuels should be researched further. The results of this research are only from one perspective, and they examine the price of SAF without considering the price of carbon allowances. Therefore, the results should be approached critically and understand the larger scale of upcoming regulatory changes. The price of carbon allowances might be a significant incentive for moving towards more sustainable aviation fuels. The price of carbon allowances and overall fuel prices should be examined parallelly to understand the full picture.

During this thesis work I was able to utilize and expand my professional and academic competences. I was able to apply my previous knowledge on fuel burn based method to calculate the CO2 emissions. In addition, my previous knowledge on the different scopes helped me to understand the scope of this study in advance. Moreover, my aviation business studies created a firm base for understanding the necessary elements in this study. Constructing a cohesive study with the right structure depended on this.

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Appendices

Appendix 1. Thesis Plan

1. Introduction	Research problem Relevance of the study Objective of the research and limitations	Background of the research Case introduction Research question and scope	Deadline: xxxx
2. Literature Review	Previous environmental and economic research Official websites and documents Other materials	- What are the main sources of emissions in aviation What is SAF What the environmental benefits of SAF What is the cost difference between SAF and Kerosene? What does the ReFuelEU Regulation entail?	Deadline: xxxx
3. Research methods	Introduction and justification of research methods	Qualitative research -> semi-structured interviews -> content analysis	Deadline: xxxx
4. Research	Semi-structured interviews Secondary research Generating the baseline scenario	Neste Oy Operating airline (anonymous) EU regulation secondary research	Deadline: xxxx
5. Analysis of the Results	Content analysis	Key data Validity and reliability	Deadline: xxxx
6. Discussion and Conclusion	Reflection of the baseline scenario to framework years Future research suggestions Personal learning outcomes	What are the scenarios for years 2025, 2030, 2035, 2040, 2045, and 2050?	Deadline: xxxx

Appendix 2. Semi-structured Interview Questions for Neste Oy.

- Which production method / pathway is used to produce SAF at Neste?
- What is the raw material used to produce SAF?
- Does SAF have an emission factor comparable to kerosene? How many tonnes of CO2 is emitted per one tonne of SAF combusted?
- What are the direct CO2 emissions of Neste's SAF?
- How do the emissions compare to kerosene? How many percentages less?
- Does SAF have any other benefits in addition to its smaller carbon emissions?
- Does an airline benefit of the emissions reductions of SAF in Scope 1 or Scope 3?

- How many times more expensive SAF is currently compared to kerosene?
- How do you expect the price of SAF to develop in the future?
- What is the current average price of SAF?
- Is there a weekly or a monthly average?

Appendix 3. Semi-structured Interview Questions for the Operating Airline

- What is the aircraft that is operated in this route?
- What is the total block time of this flight?
- Who are your current fuel suppliers for this route?
- Is SAF currently used on this exact route?
- Which way do you follow your fuel consumption on this route?
- Is the flight fueled every time before the flight? Is tankering practiced on this route?
- Do you follow the fuel quantities at block off and block on? If yes, **what is the average consumption per one leg?**
- Do you follow the fuel consumption based on the fuel uplift datasheet? If yes, **what is the average consumption per one leg?**
- Is there a fuel consumption average per one leg, week or month?

- How much fuel on average does one operation require?
- What are the current average fuel costs for one operation?
- What is the average fuel cost per one month for this specific route?
- Is traffic expected to grow in the future?