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Taking Flight Towards a Greener Future: Steps Airlines Can Take to Reduce Emissions

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Bachelor Thesis 15 Credits
Bachelor Programme in Aviation, Later Part
FLYL01
Spring Term 2023

Supervisor: Elna Heimdal Nilsson

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Abstract

Background: For decades, aviation has been an important part of society and with its growth comes the increased environmental impact and the challenge to reduce this adversary effect and move towards sustainability. **Objective:** Find out how airlines can reduce their emissions and become more sustainable. **Method:** A literature review was conducted including scientific articles, data from Airbus and one airline to answer the problem definition. **Results:** Three pillars were identified in order to achieve the objective: efficient ground and aircraft operation, the use of sustainable aviation fuel, and advancement in aircraft and engine technology. **Conclusion:** While there are several challenges in establishing a sustainable airline, the adoption of sustainable aviation fuel at an accessible price is essential for a more significant impact on the environment. Today, the maximum blending ratio for sustainable aviation fuel stands up to 50 percent, but we need to reach 100 percent. In addition to technological advancement in fuel types, there are some prompt actions we can take today for an immediate effect and impact, such as efficient ground and aircraft operations. Alongside this, crew education and motivation are imperative to achieve fuel savings and emission reduction. However, an airline's financial stability and business model may impede their commitment to prioritizing sustainability measures.

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Table of Contents

List of Abbreviations

Abbreviation	Definition
14R	Runway 14 Right
32R	Runway 32 Right
A320	Airbus 320
A321	Airbus 321
A330	Airbus 330
A340	Airbus 340
A350	Airbus 350
A380	Airbus 380
ACMI	Aircraft Crew Maintenance and Insurance
AGL	Above Ground Level
AIC	Aircraft-Induced Clouds
ALT	Altitude
AMF	Air Management Function
APU	Auxiliary Power Units
ASK	Available Seat Kilometer
ATC	Air Traffic Control
B737	Boeing 737
CDL	Configuration Deviation List
CEO	Classic Engine Option
CFP	Computerized Flight Plan
CI	Cost Index
CO	Carbon Monoxide
CO_2	Carbon dioxide
CONF	Configuration
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CTT	Christer Tom Thomas
DPO	Descent Profile Optimisation
EASA	European Aviation Safety Agency
ECON	Economic
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FCOM	Flight Crew Operating Manual
FDP	Final Descent Point
FL	Flight Level
FMS	Flight Management System
GPU	Ground Power Unit
H_2	Hydrogen
HC	HydroCarbon
HEPA	High Efficiency Particle Arrestor
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
IFO	IDLE Factor Optimizer
IT	Information Technology
Jet A1	Traditional Jet Fuel
LH_2	Liquid Hydrogen
LNG	Liquid Natural Gas
LO	Low
LTA	Large Twin Aisle
MD80	McDonnell Douglas 80
MEL	Minimum Equipment List
NEO	New Engine Option
Nm	Nautical miles
NO_x	Nitrogen Oxides
R	Regional
RNP AR	Required Navigation Performance Authorization Required
S	Small
SA	Single Aisle
SAF	Sustainable Aviation Fuel
SAS	Scandinavian Airlines System
SBTi	Science Based Targets initiative
SDG	Sustainable Development Goals
SET	Single Engine Taxi
SETI	Single Engine Taxi-In
SETO	Single Engine Taxi Out
SETWA	Single Engine Taxi Without APU
SMTA	Small Medium Twin aisle
T/O	Take-Off
TA	Twin Aisle
TEM	Threat and Error Management
TOGA	Take-Off/Go Around
UNDP	United Nations Development Programme
ZEROe	Zero-emission

Introduction

The aviation industry has been a crucial part of the human economy and society for decades, by providing a faster and efficient way to travel and connecting people from all around the world. Before air travel, the other forms of transportation were often inefficient and took a very long time. For the prosperity of a society it is crucial to have flights that can carry out vital services such as ambulances, fire fighting and other critical services available and accessible at all times. However, the growth of air travel comes at significant cost on the environment, particularly in terms of greenhouse gas emissions. Sustainability has risen to the top of the priority list for governments, consumers and the industry during the past few years.

Background

Sustainability defined according to the Brundtland report (1987) "is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 41). This is based on three connected dimensions: environment, economy and society.

1. Environmental sustainability: Focuses on protecting and preserving the natural environment and its resources for future generations.
2. Economic sustainability: Focuses on using resources in a way that supports long-term economic growth and development.
3. Social sustainability: Focuses on meeting the needs of current and future generations in terms of social well-being, including issues such as equity, social justice, and community health.

In 2015 the United Nations Development Programme (UNDP) set 17 Sustainable Development Goals (SDGs) to be achieved by 2030. The overall goal is to end poverty, protect the planet, and to ensure peace and prosperity for all. SDG number 13 specifically addresses climate action and calls for urgent measures to combat climate change and its impacts. The International Civil Aviation Organization (ICAO) defines sustainability in aviation as the balanced and responsible management of environmental, economic, and social impacts, while ensuring the long-term viability and growth of the aviation sector (ICAO, 2016). The problem with aviation concerning general sustainability is that it has a significant environmental impact, particularly in terms of emissions and noise pollution (IPCC, 2014).

Emissions produced in the combustion of fuel in the aviation engine both result in an impact on the climate and have harmful effects on health in the vicinity of airports. Climate effects and environmental/health effects of aviation are closely linked but still need to be defined as two different problems for society and people. These two problems also fall under different regulatory frameworks, where regulations around climate emissions are governed more internationally, while the local environment around the airport is governed by national/regional/local regulatory frameworks.

Emissions from aviation affect climate by the release of greenhouse gases and under some circumstances also formation of contrails. Carbon dioxide (CO_2) is considered the most alarming greenhouse gas, because it is the largest contributor to global warming and climate change. Heat is trapped in the atmosphere by CO_2, which raises temperatures, melts the ice caps and causes sea levels to rise. Moreover, during combustion, airplane engines release nitrogen oxides (NO_x). Ground-level ozone is a dangerous air pollutant that impacts both human health and the environment, and NO_x helps to create it. Ozone at ground level can harm crops, trees, and other vegetation in addition to causing respiratory issues like asthma (WHO, 2016). In 2021 the aviation industry was responsible for about two percent of global greenhouse gas emissions and this is expected to increase in the coming years according to the International Energy Agency (IEA) tracking report (IEA, 2022). Additionally, aircraft noise can have negative impacts on communities near airports, as well as on wildlife (Alquezar & Macedo, 2019), and Aircraft-Induced Clouds (AIC) form from the exhaust of airplanes, affecting the earth's climate by reflecting sunlight and trapping the heat (Sherry & Thompson, 2020).

Air travel is a contributor to climate change so there is a growing need to reduce the environmental impact of aviation. The airlines can act to these challenges through various initiatives, such as fuel efficiency improvements, the use of alternative fuels, and the development of more sustainable aircraft designs. Implementing more efficient operations can also play a big role in reducing costs and emissions. By reducing flight time through optimizing routes, and increasing the use of new technology, airlines can reduce fuel consumption and emissions and at the same time cut costs. From the author's experience and knowledge as pilots, strategies that are known for reducing emissions are listed below, and will be elaborated in greater detail in subsequent sections of this report.

- ➢ Use more fuel-efficient aircrafts: Airlines can utilize more fuel-efficient aircraft models, such as more recent versions of aircrafts with more cutting-edge engines and lightweight constructions. These aircrafts can travel the same distance on less fuel because of their improved aerodynamic efficiency and more fuel efficient engines.
- ➢ Employ alternative fuels: Instead of conventional fossil fuels, airlines may choose biofuels instead, which are created from renewable resources including algae, vegetable oil, and animal fat. Biofuels can aid in lowering the carbon footprint of the aviation sector since they have already absorbed CO_2 during their growth, utilizing them is thought to result in lower net carbon emissions than using conventional fossil fuels.
- ➢ Enhance flight routes: Airlines can enhance flight patterns to shorten travel times and conserve fuel. By taking more direct routes and avoiding pointless detours, this may be accomplished.
- ➢ Decrease aircraft weight: Airlines can reduce the weight of the aircraft by using lighter materials, carrying less water, catering, and reducing the amount of unnecessary equipment on board which results in less fuel burn.
- ➢ Improve ground operations: Airlines can improve ground operations by using electric or hybrid ground vehicles, reducing the time spent idling and optimizing the use of auxiliary power units[1] (APUs). From the start of engines to engine shutdown, the airlines can implement fuel saving techniques and operations such as Single Engine Taxi[2] (SET) in and out to reduce fuel burn.

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[1] An auxiliary power unit APU is a small engine located at the rear of an aircraft which provides power to start the engines and electrical systems while the aircraft is on the ground. It can also provide power to the aircraft's systems in case of an emergency.

[2] Single engine taxi is a technique used in aviation where only one engine of a multi-engine aircraft is used to maneuver the plane on the ground.

- Adopt sustainable practices: Airlines can reduce waste, recycle, and use renewable energy sources as examples of sustainable measures to lower their overall carbon footprint.

The aviation industry as a whole has set ambitious goals to reduce its carbon emissions and improve its overall sustainability performance. The pursuit of the goals outlined above comes with several challenges, including the need for airlines to incur higher initial costs. Additionally, implementing new procedures to enhance operational efficiency can be complex and might require significant changes to existing regulations. Long-term, the aviation industry has a critical role to play in addressing the environmental and sustainability challenges of the 21st century, implementing efficient operations is a necessity in order to achieve those goals.

So what are the operating costs of an airline and how much of it is the fuel cost? According to Belobaba et al. (2009) an airline operating cost consists of the following:

- Fuel costs: The cost of jet fuel, which can vary depending on market prices.
- Labor costs: The cost of pilots, flight attendants, ground crew, and other staff members.
- Maintenance costs: The cost of maintaining and repairing aircraft, including scheduled maintenance and unscheduled repairs.
- Aircraft leasing or purchase costs: The cost of leasing or purchasing aircraft for the airline's fleet.
- Landing fees and airport charges: The cost of using airport facilities, including landing fees, gate fees, and other charges.
- Insurance costs: The cost of insuring the airline's operations, including liability insurance and hull insurance for aircraft.
- Marketing and advertising costs: The cost of marketing and advertising the airline's services to customers.
- Administrative costs: The cost of running the airline's headquarters and administrative operations, including salaries, office space, and other expenses.
- IT and technology costs: The cost of implementing and maintaining technology systems for the airline's operations, including reservations systems, flight planning systems, and other IT infrastructure.

These costs can vary depending on the airline's size, route network, and business model. Figure 1 illustrates the percentage of airline expenses in a circular diagram, giving an overview of airline operating costs. Fuel prices and labor costs carry half of the operating cost of an airline and are subject to frequent fluctuations due to various factors, such as changes in global oil prices, geopolitical tensions, supply and demand imbalances, as well as shifts in the labor market conditions and regulations.

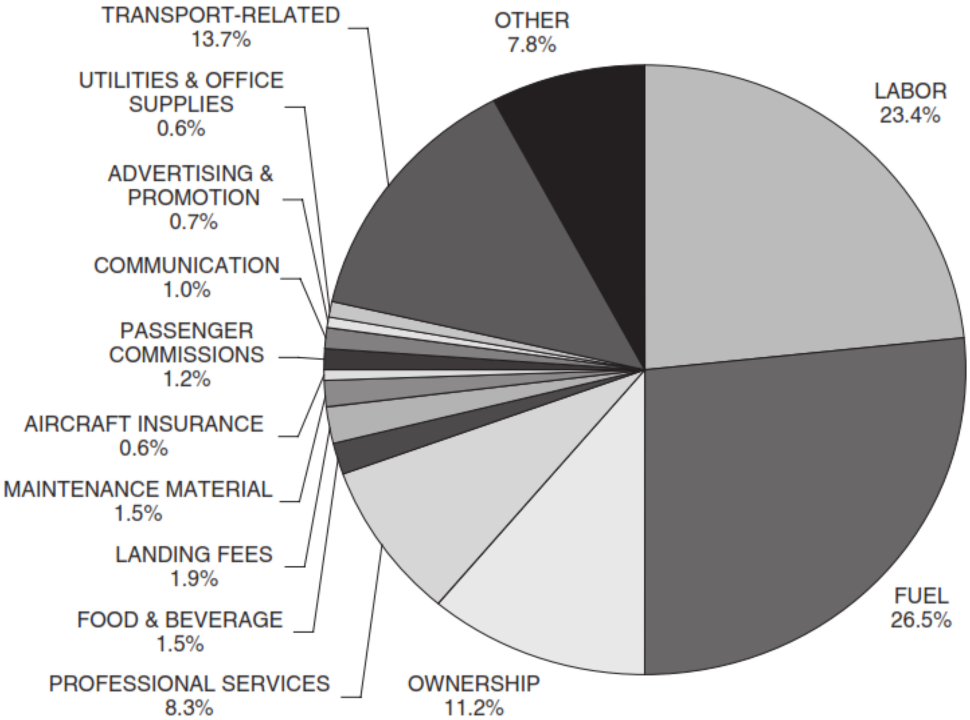

Figure 1. Example of operating cost of an airline in percentage. Source (Belobaba et al., 2009).

Purpose

The purpose of this paper is to evaluate the literature that has already been written about aviation sustainability and will suggest actions that airlines can take to cut back on emissions, as there are only certain factors an airline can control. As mentioned, air travel is expected to increase in the coming years, and as the aviation sector is one of the largest producers of greenhouse gas emissions globally, it is crucial that the sector take steps to reduce its negative environmental effects. This essay aims to offer a thorough understanding of the steps airlines can take to reduce their environmental impact by reviewing the most recent research and recommendations on sustainable aviation practices. The results of this literature review's analysis will be utilized to provide airlines with specific suggestions on how to reduce their environmental impact and encourage the sector's sustainable growth.

Question

What steps can an airline take to reduce its environmental impact and move towards more sustainable practices?

Method

The method used for this literature study involves searching electronic databases including Google Scholar and LUBsearch for scientific reports, peer-reviewed articles and studies related to the topic of sustainability in aviation and steps airlines can take to reduce emissions. Keywords used in different combinations to find relevant articles are: aviation, sustainable, fuel, management, and development. Some articles have been gained from other field experts. The study focuses only on commercial fixed-wing[3] airplanes. The authors have sought different airlines for data on how they work with sustainability. However, in certain instances, the authors' requests were either unanswered or denied due to the confidentiality of the information in the reports. One manager did respond to questions asked and attached as Appendix 1 with fuel data as Appendix 2. Airbus and Boeing were contacted to procure information and sustainability reports pertaining to aircraft operations. The authors also participated in the final conference "Fossilfritt flyg I NORRA SVERIGE" which took place in February 2023.

The value of the different kinds of data and reports differs depending on the source or the purpose of the objective they were designed to serve. Scientific reports and articles are based on empirical evidence collected through systematic and objective research methods. The reports are subjected to peer review to ensure compliance with established standards and to validate the reliability and credibility of the results (Backman, 2016). On the other hand, authoritative reports typically offer a comprehensive overview of a particular subject and are often written by experts in the field. Such reports can wield significant influence on policy decisions but may be influenced by political or industry interests, resulting in potential bias (Backman, 2016). Company reports, in turn, may also be biased due to the tendency to portray the company in the most favorable light. Such reports may use language and data to highlight successes and downplay failures. Company reports are frequently drafted by management or public relations teams, who may have a vested interest in presenting the company in a positive light. This bias can either be deliberate or unintentional. Greenwashing is the practice of making false or exaggerated claims about the environmental sustainability of a product or service (Harrocks & McMurchie, 2022). Greenwashing has become a major concern in the aviation industry today, as airlines attempt to project an image of environmental responsibility without making substantial adjustments to their operations.

The primary data relies on data obtained from the aircraft manufacturer Airbus, specifically pertaining to the Airbus 320 (A320) model. Some data from Boeing 737 (B737) and McDonnell Douglas 80 (MD80) models are also incorporated. The A320 and B737 are the most commonly used aircrafts in the industry. The B737, A320, and MD-80 are classified as Single Aisle (SA) twin-engined jet airplanes designed for commercial mid-range flights, with passenger capacity ranging up to 240, depending on the airplane's version and configuration. The Airbus 330 (A330) and Airbus 340 (A340) models belong to the Small Medium Twin Aisle (SMTA) category and feature two or four engines, and are intended for commercial long-range flights, with a passenger capacity of up to 350 (Airbus, 2023a). Finally, the Airbus 350 (A350) and Airbus 380 (A380) models belong to the Large Twin Aisle (LTA) category, featuring two or four engines and a wide-body design intended for commercial long-range flights. These models can carry up to 440 passengers in the case of the A350 (Airbus, 2023b) and up to 545 passengers in the A380 (Airbus, 2021), contingent on the specific version and configuration of the airplane.

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[3] Fixed-wing aircraft refers to an airplane with wings that generate lift to enable flight. Unlike helicopters and other aircraft varieties, the wings of a fixed-wing aircraft remain stationary during flight.

Limitations

The objective of this study was to gather data from various airlines; however, several airlines either did not respond to our request or declined to share data on the grounds of confidentiality. Consequently, the study was conducted as a literature review by searching for relevant articles. The research papers used were accessible through the internet and with addition of some data from Airbus. Only literature in English and Swedish was used.

The research measures do not comprehensively cover all dimensions of sustainability, and instead prioritize solely on fuel economy and CO_2 reduction. Effective implementation of such measures may necessitate substantial investments in terms of finances, time, and resources. Additionally, certain individuals within the company may perceive the measures as excessively limiting or arduous to adhere to.

The authors of this study have extensive experience as commercial pilots, with one operated turboprop aircraft in the past and the other currently flying the A320 and holding instructor and examiner privileges on this aircraft type. This experience may have influenced the authors decision to focus their research primarily on the A320 and Airbus. Nonetheless, the authors have tried to counteract any bias.

The operational part of the study is subject to a specific limitation in that the authors relied exclusively on data from Airbus. While it is true that the laws of physics and regulations apply uniformly to all aircraft, it is also acknowledged that the magnitude of fuel savings and emissions reductions may vary across different aircraft types and operating scenarios. However, the procedures outlined in the study are likely to yield significant benefits in terms of fuel efficiency and emissions reductions for all types of aircraft and operations. Despite the potential differences in numerical outcomes, the application of these procedures can still be considered a beneficial practice that is worthy of adoption by airlines and other stakeholders across the aviation industry.

Instead of relying on a potentially selective presentation of data from Airbus, a more accurate representation of reality could have been presented if actual raw data from different companies had been acquired. This would have allowed for a more thorough evaluation of the effectiveness and prospective impact of the proposed solutions suggested by Airbus, as we could have compared the claims of Airbus versus the reality in the airlines applying these practices.

Result

Through their research, the authors have identified three essential pillars that may contribute to the reduction of carbon emissions for an airline:

1. Efficient ground and aircraft operation,
2. The use of sustainable aviation fuels
3. Advancements in aircraft and engine technology.

These pillars are further divided into present, near future, and future actions. This paper will go into each of these pillars, highlighting the necessary actions for an airline to take in each of these timeframes in order to reduce significant carbon footprints.

Efficient Ground and Aircraft Operation

The authors will examine the various methodologies, drawing primarily on data provided by Airbus, to elucidate the concepts and procedures that are standard in aviation but may pose challenges for individuals unfamiliar with the field. For better comprehension, these technical terms and procedures will be supplemented with explanatory footnotes.

Choosing Correct Cost Index (CI)

The CI is an important factor for airlines when planning flights, it is a metric that airlines use to balance the cost of fuel against the cost of time taken to complete a flight, the cost of time refers to the expenses incurred by airlines due to factors such as flight duration, aircraft utilization, crew costs, airport charges and other time-related costs, see Figure 2, and selecting the optimal CI value is essential for achieving optimal fuel efficiency while retaining time efficiency (Roberson, 2007). The CI value ranges from 0, indicating minimal fuel consumption and maximum range, to 999, representing the minimum flight time and maximum speed.

In equation form: $$\text{CI} = \frac{\text{Time cost} \sim \$/\text{hr}}{\text{Fuel cost} \sim \text{cents/lb}}$$

Figure 2. Cost Index formula in US dollars, Source (Roberson, 2007).

On the one hand, a high CI value may result in faster travel times, which can be attractive to passengers and enable airlines to provide more frequent flights. Unfortunately, this can also result in increased fuel consumption and emissions, which is contrary to Airbus's sustainability goals (Airbus-WIN, 2023). On the other hand, selecting a low CI may result in lower fuel consumption, saving airlines money and maybe leading to lower ticket prices. However, a lower CI value may also result in longer flight durations, which customers may find less appealing.

To obtain optimal fuel economy, airlines must take into account a variety of parameters, including aircraft type, route distance, weather conditions, and fuel pricing. For instance, Airbus-WIN (2023) advises airlines to assess the trade-off between a higher CI value for short-haul flights, where time efficiency may be more important and a lower CI value for long-haul flights, when fuel efficiency may be more important due to the greater distance. Increasing the CI from 0 to 20 reduces the A320's flight time by 15 minutes, while increasing fuel consumption by 200 kg, which is two percent increased fuel consumption on a 3700 km flight (Airbus, 2004).

Airlines must monitor and alter their CI values in reaction to fluctuating fuel prices or other external factors that may affect the equilibrium between time and fuel economy. Airbus's sustainability processes highlight the need to strike the optimal balance between time and fuel economy in order to reduce fuel consumption and emissions (Airbus-WIN, 2023).

A flight evaluation presented in Roberson (2007) article, displayed very interesting findings. A detailed assessment was done of the ideal CI for the 737 and MD-80 fleets by an airline that is not mentioned by name in the article (Roberson, 2007). The ideal CI was discovered to be 12 for all 737 variants, and 22 for the MD-80. Table 1 displays how altering the CI for a typical 1,000-mile journey can affect trip duration and possible savings over the course of a year. With a small impact on the schedule, the modification of CI not only leads to annual fuel savings for the airline of $4 million to $5 million US dollars but also aids to reduce the airline's carbon footprint by lowering CO_2 emissions.

Table 1.
Cost index impact[4] on time per flight and annual cost savings by utilizing optimum CI versus the current CI. Source (Roberson, 2007).

FLEET	CURRENT COST INDEX	OPTIMUM COST INDEX	TIME IMPACT MINUTES	ANNUAL COST SAVINGS ($000's)
737-400	30	12	+1	US$754 – $771
737-700	45	12	+3	US$1,790 – $1,971
MD-80	40	22	+2	US$319 – $431

Operational Measures for Immediate Reduction of Fuel Consumption and Emissions

The authors of the present work made a diligent effort through different channels and connections to obtain comprehensive information on fuel consumption and fuel savings, which would have provided useful insights into the environmental performance of Airbus and Boeing. Regrettably, direct access to such data was not granted due to confidentiality concerns. Instead, the authors were provided with links to data available on the website as well as publicly known operational procedures from Airbus. In January 2023 Airbus World Instructor News (Airbus-WIN, 2023) published in WIN series section sustainability movies in order to aid the airline's becoming sustainable and to train their staff. The procedures and techniques will be presented below from each episode.

Airbus categorizes the various stages of a flight into nine distinct phases, namely dispatch[5], preliminary cockpit preparation and exterior walkaround, cockpit preparation before pushback and start, single-engine taxi-out, climb, cruise, descent, holding[6] and approach, and single-engine taxi-in (Airbus-WIN, 2023).

Dispatch. Airbus recommends reducing the weight of the aircraft as much as possible, since this directly leads to lower fuel consumption for the whole flight and affects all phases. According to data from Airbus, if the aircraft weight is reduced by 100 kg, the fuel saving could be from 20 up to 40 kg depending on the aircraft type per flight, see Table 2. This can be achieved through measures such as reducing unnecessary cargo, baggage, avoiding over-fueling, and optimizing the use of onboard equipment.

Potable water[7] use and carriage: Depending on the route, number of passengers, and global conditions, airlines can take water use and carriage into consideration in order to optimize fuel consumption. For instance, carrying less portable water on shorter flights or in cooler climates can reduce the aircraft's weight and save fuel.

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[4] The impact on time refers to how the choice of cost index can affect the duration of the flight time, plus for longer and minus for shorter.

[5] Dispatch is the process of planning and preparing the flight before take-off. It involves coordinating various factors such as weather, fuel, crew and airport facilities to ensure that the flight can be conducted safely and efficiently.

[6] Holding is a procedure generally utilized by ATC to delay the arrivals at an airport. The pilot must follow a specific oval-shaped pattern in the sky, usually located near the airport.

[7] Potable water is defined as drinking water that is suitable for both passengers and crew.

Table 2.

Aircraft operating weight reduced by 100 kg fuel saving per sector[8] *based on a computation for flight at max range, with a payload of 80%. Source (Airbus-WIN, 2023, WIN Series:EP1 Dispatch).*

Savings per Sector	**Fuel (kg)**	**CO_2 (kg)**
Single Aisle (A220/A320)	20	63
Twin Aisle (A330/A350)	36	113

Fuel tankering is the practice of carrying additional fuel on board the aircraft due to lower fuel prices at the departing station. However, it has an effect on engine wear, wheel, and brakes, extra fuel burn, and cost of extra CO_2. Therefore, airlines should evaluate the cost and benefits of fuel tankering before implementing it.

The maximum Flying Level[9] (FL) may be penalized by Minimum Equipment List[10] (MEL) and Configuration Deviation List[11] (CDL) items, which might result in a rise in fuel usage. These are the lists of hardware and software requirements for the safe operation of the aircraft. The performance of the aircraft may be impacted if an item on the MEL or CDL list is inoperative or missing. The inoperative system may result in a lower maximum operating altitude leading to increased fuel consumption. Similarly to this, a missing CDL item might cause more drag and hence use more fuel see Table 3 and Table 4. Maintaining the aircraft properly and making sure that no MEL or CDL items are open[12] can help to reduce the effect of MEL and CDL items on fuel usage.

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[8] Sectors refers to a flight from departure airport to destination airport.

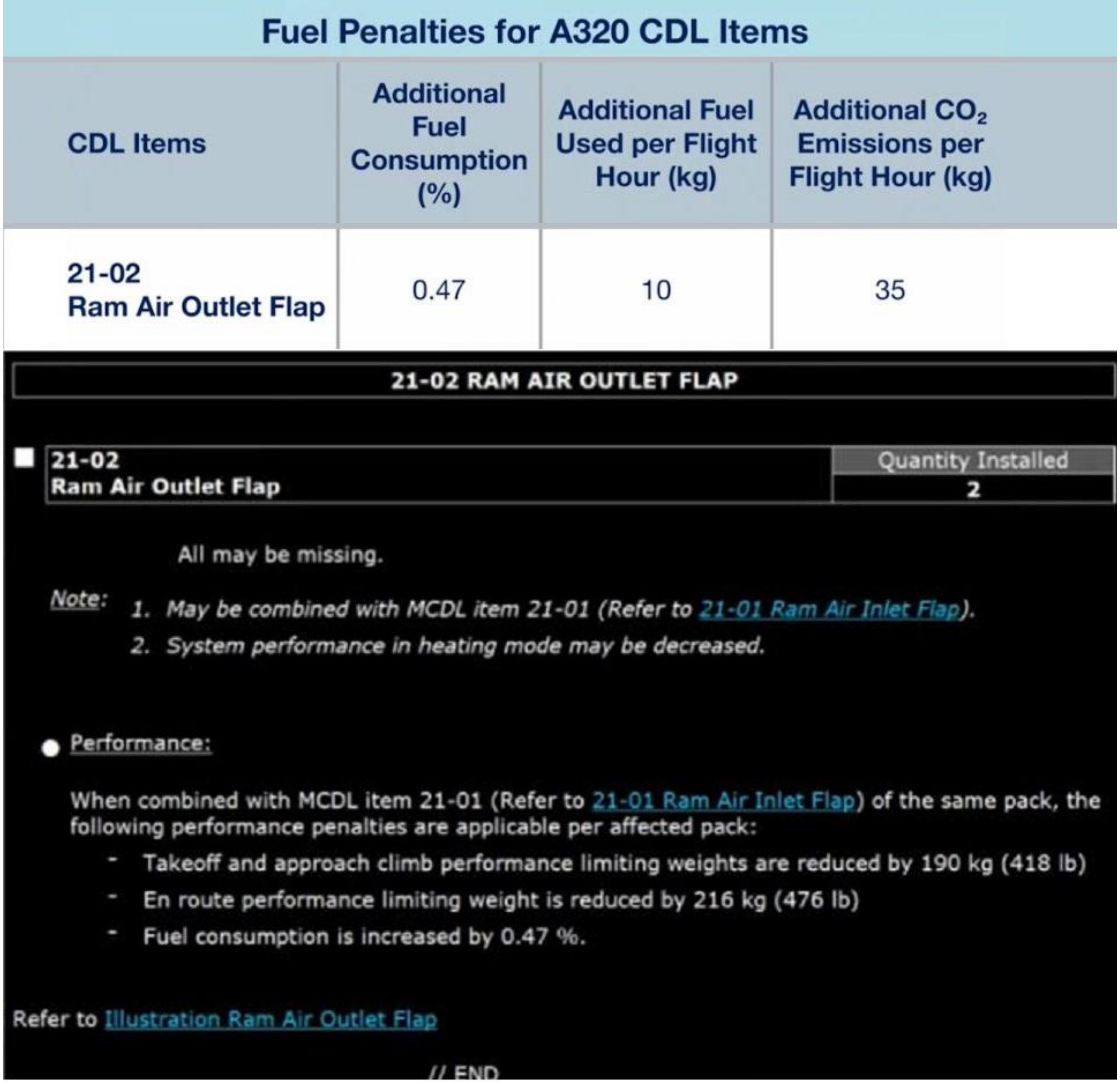
[9] Flight Level refers to the altitude at which an aircraft is flying, expressed in hundred of feets. For instance, FL300 is equal to 30,000 feet which is equal to around 9,144 m.

[10] MEL is a document that specifies the minimum equipment requirements for a particular aircraft to be considered airworthy. It allows an aircraft to continue operating with some non-critical equipment inoperative, as long as it does not compromise safety.

[11] CDL is a document that outlines the allowable deviations from the standard configuration of an aircraft, such as missing a secondary aircraft body part. It is used when an aircraft is not in its usual configuration due to maintenance, repairs, or other reasons. The CDL ensures that the aircraft is still safe to fly and meets all necessary regulations.

[12] An open MEL or CDL item refers to a piece of equipment that is listed as temporarily inoperable and can be deferred while the aircraft remains safe to operate within specific limits, provided that any required procedures or restrictions are followed.

Table 3.
Fuel penalties and CO_2 emissions per hour flight on A320 with a certain CDL restriction. Source (Airbus-WIN, 2023, Win Series 2023:EP1 Dispatch) and (CDL A320).



Fuel Penalties for A320 CDL Items

CDL Items	Additional Fuel Consumption (%)	Additional Fuel Used per Flight Hour (kg)	Additional CO_2 Emissions per Flight Hour (kg)
21-02 **Ram Air Outlet Flap**	0.47	10	35

21-02 RAM AIR OUTLET FLAP

■ **21-02** **Ram Air Outlet Flap**	Quantity Installed **2**

All may be missing.

Note: 1. *May be combined with MCDL item 21-01 (Refer to 21-01 Ram Air Inlet Flap).*
2. *System performance in heating mode may be decreased.*

● Performance:

When combined with MCDL item 21-01 (Refer to 21-01 Ram Air Inlet Flap) of the same pack, the following performance penalties are applicable per affected pack:

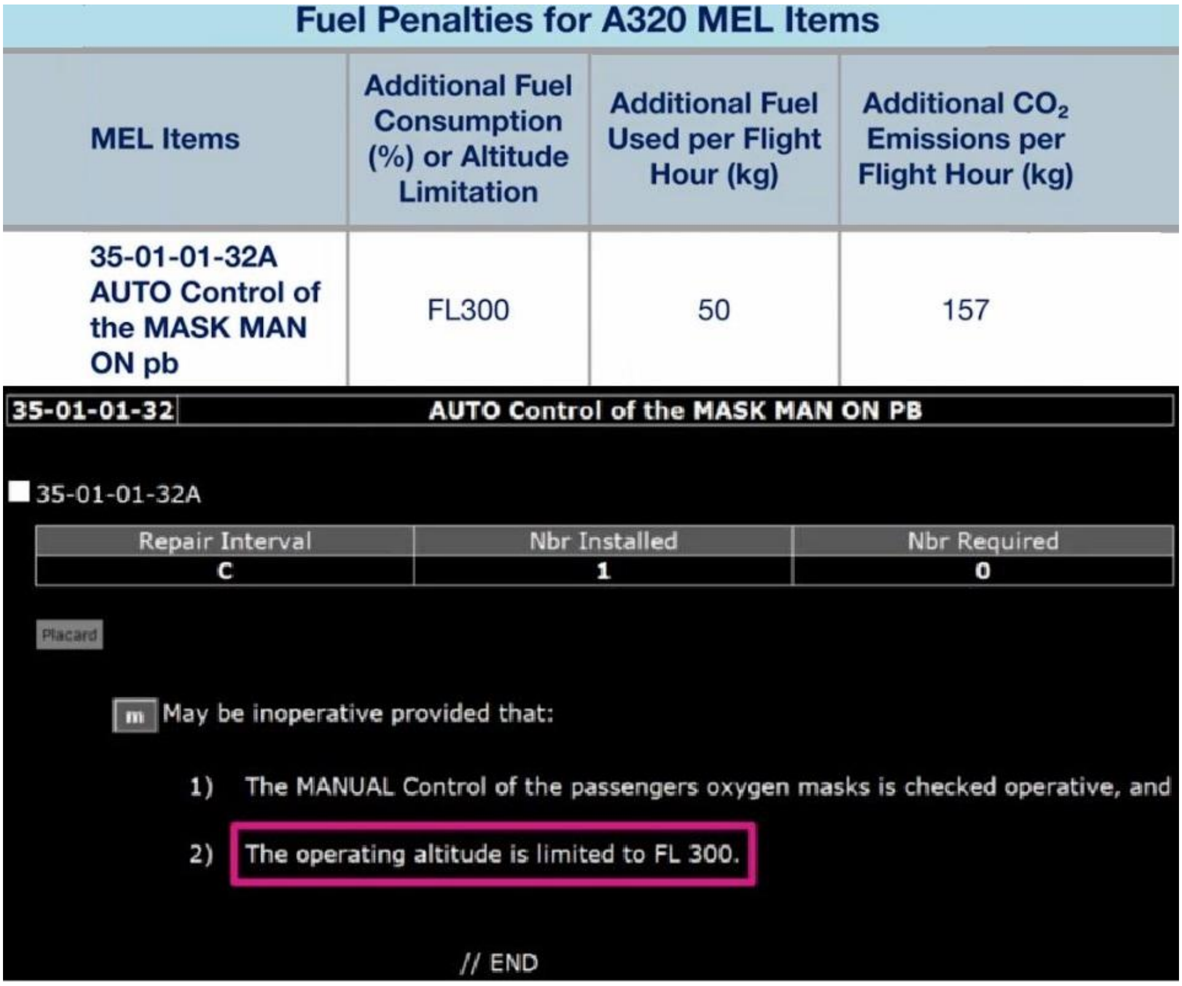
- Takeoff and approach climb performance limiting weights are reduced by 190 kg (418 lb)
- En route performance limiting weight is reduced by 216 kg (476 lb)
- Fuel consumption is increased by 0.47 %.

Refer to Illustration Ram Air Outlet Flap

// END

Table 4.

Fuel penalties and CO_2 emissions per hour flight on A320 with a certain MEL restriction. Source (Airbus-WIN, 2023, Win Series 2023:EP1 Dispatch) and (MEL A320).



Fuel Penalties for A320 MEL Items

MEL Items	Additional Fuel Consumption (%) or Altitude Limitation	Additional Fuel Used per Flight Hour (kg)	Additional CO_2 Emissions per Flight Hour (kg)
35-01-01-32A AUTO Control of the MASK MAN ON pb	FL300	50	157

35-01-01-32 AUTO Control of the MASK MAN ON PB

☐ 35-01-01-32A

Repair Interval	Nbr Installed	Nbr Required
C	1	0

May be inoperative provided that:

1) The MANUAL Control of the passengers oxygen masks is checked operative, and

2) The operating altitude is limited to FL 300.

// END

Preliminary Cockpit Preparation and Exterior Walkaround. Delaying APU start: By delaying the APU start, savings of 130 kg of fuel per hour can be achieved on the A320 or selecting one or both packs[13]-off if ground power is not available can save 20 to 30 kg per hour if APU is operating, see Table 5. It is worth noting that in addition to the potential fuel and cost savings resulting, these practices also contribute to improved air quality at airports, as less exhaust is released in areas where individuals are working (Stettler et al., 2018). These actions may result in a reduction of CO_2 emissions and other air pollutants, which may result in reduced negative impact on the environment and human health in the long term.

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[13] The PACKS system ensures that both passengers and crew have a comfortable flight by supplying heated or cooled air to the cabin of an airplane. On the A320, there are two PACKS that are managed by the flight crew via the Environmental Control System panel.

Table 5.
Possible fuel and CO_2 *emissions savings kg/h with APU, One pack or both pack off on ground. Source (Airbus-WIN, 2023, Win Series 2023:EP2 Preliminary Cockpit Preparation and Exterior Walkround).*

Aircraft Type	Electrical Generator 2 PACKS ON	Electrical Generator 1 PACK ON 1 PACK OFF	Electrical Generator 2 PACKS OFF	CO_2 Emissions (kg/h)
A300	185	140	125	580
A320	130	110	100	410
A330	215	155	140	680

Aircraft body irregularities: Irregularities in the aircraft body such as fuselage panels, flight control surfaces, seals, peeling paint, and dirt, can cause additional fuel penalties. Therefore, the crew should ensure that the aircraft body is regularly clean during walkaround and report without delay to maintenance any findings, so that the aircraft is maintained at the first opportunity to be fuel efficient again.

Cockpit Preparation Before Pushback or Start. Data insertion in Flight Management System[14] (FMS): The maximum altitude for a flight is not necessarily the most efficient option as the wind speed may vary at lower altitudes, providing either a stronger tailwind or a weaker headwind. As such, selecting a lower altitude could prove advantageous. It is therefore imperative to input accurate wind and temperature data into the FMS in order to enable it to accurately compute and predict the most fuel-efficient and optimal flight path. However, if the crew is under time pressure and cannot input detailed wind and temperature data, it is recommended to at least enter the average wind in the FMS to ensure a reasonable estimation of the optimal flight path.

Selecting pack flow[15] to low: Selecting pack flow to low on the air conditioning panel if passenger numbers allow, will reduce fuel consumption by up to 0.5% of the trip fuel (Airbus-WIN, 2023, Win Series 2023:EP3 Cockpit preparation Before Push back or Start). See Figure 3 for the effect on A320. The air conditioning consumes a significant amount of fuel, and reducing the flow may lead to significant fuel savings.

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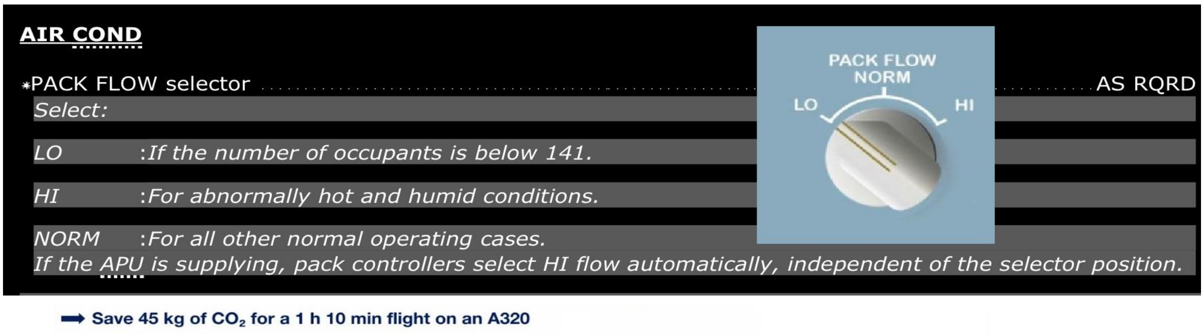
[14] FMS is a computer installed in an aircraft that automates many in-flight tasks, such as navigating, flight planning, and performance calculations. It helps pilots manage flight routes and make decisions by providing real-time information about weather conditions, air traffic and other important flight parameters.

[15] Pack flow selection is the process of choosing the amount of air to be pumped into an aircraft cabin by the air conditioning system. It can be set to low, normal or high, depending on factors such as the number of passengers, the outside temperature and the altitude of the aircraft.



AIR COND

*PACK FLOW selector .... AS RQRD

Select:

LO :If the number of occupants is below 141.

HI :For abnormally hot and humid conditions.

NORM :For all other normal operating cases.
If the APU is supplying, pack controllers select HI flow automatically, independent of the selector position.

➡ **Save 45 kg of CO_2 for a 1 h 10 min flight on an A320**

Figure 3. Example of savings with the selector in LO mode. Source (Airbus-WIN, 2023, Win Series 2023:EP3 Cockpit preparation Before Push back or Start) and A320 FCOM).

Reducing thrust reduction and acceleration[16]: If noise abatement and performance allows, reducing thrust reduction and acceleration contributes to fuel saving due to the fact that it enables earlier cleaning up the flaps and slats, thus achieving a more efficient and aerodynamic configuration with minimum drag. By regulation (EASA, 2023) the earliest allowed thrust reduction is 400 ft Above Ground Level[17] (AGL). However, a majority of airlines have shifted from 1500 ft AGL to 800 ft AGL and Table 7 presents the fuel savings and emissions that can be achieved through this technique.

Table 7.
Fuel and CO_2 emission savings if using 800 ft instead of 1500 ft AGL thrust reduction per flight. Source (Airbus-WIN, 2023, Win Series 2023:EP3 Cockpit preparation Before Push back or Start).

Aircraft	Fuel (kg)	CO_2 (kg)
A220-300	5	15
A320ceo	16	50
A320neo	10	31
A330-300	34	107
A350-900	23	72
A380	110	346

Choosing the shortest taxi time and departure: Selecting the shortest taxi time and departure procedure can reduce fuel consumption. This can be achieved through measures such as using the shortest taxi by departing from a runway with a tailwind if performance allows, avoiding unnecessary stops, and selecting the most direct flight path toward the destination. Figure 4 below is an example of using the opposite runway with a tailwind of

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[16] Thrust reduction and acceleration altitude are techniques used in aviation to save fuel and reduce noise. During take-off, the engines are initially set to high power but can be reduced to a lower power setting once a certain altitude is reached. This helps to save fuel and reduce noise. Similarly, during climb, the aircraft may accelerate to a higher speed once a certain altitude is reached, which may also save fuel.

[17] AGL is used in aviation to describe an aircraft or an object's height above the ground in feet, mostly in civil aviation.

32R instead of 14R shows the savings in taxi time, fuel and emissions. However, selecting a shorter taxiway or departure runway is greatly influenced by a number of factors, including incoming and outgoing aviation traffic, and the decision is made by air traffic control, not the pilots.

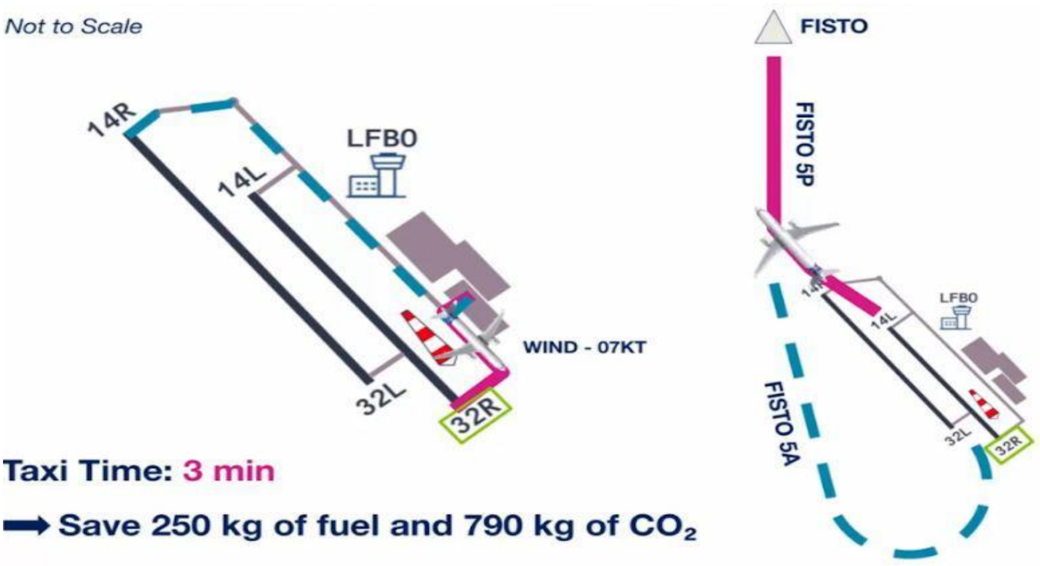


Figure 4. Fuel and CO_2 emissions savings by choosing the shortest distance to taxi and fly. Source (Airbus-WIN, 2023, Win Series 2023:EP3 Cockpit preparation Before Push back or Start).

Delaying engine start: Delaying engine start can save significant amounts of fuel, see Table 8. The crew should avoid if possible standing with the engines running and waiting. This is because engines consume a significant amount of fuel, even when idling.

Table 8.

Fuel and CO_2 emissions savings every ten minutes. Source (Airbus-WIN, 2023, Win Series 2023:EP4 Single Engine Taxi-Out).

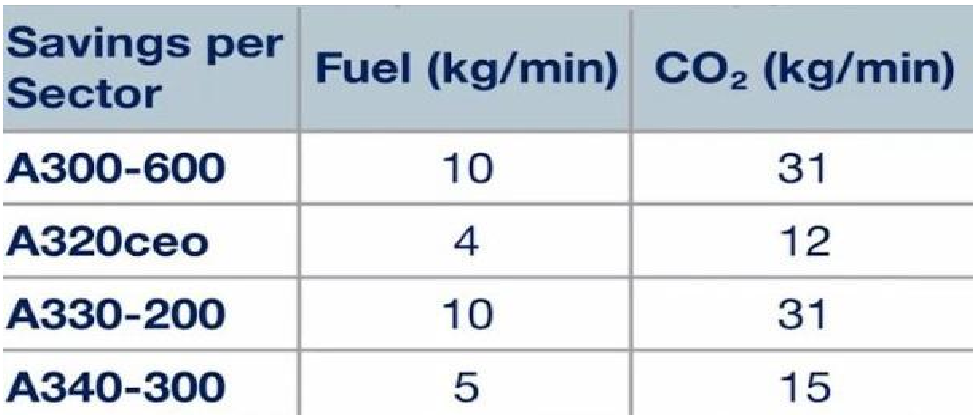
Saving per Sector	Fuel (kg)	CO_2 (kg)
A300/A310	260	820
A320 family	100	315
A330 family	200	630
A340-200/300	220	690
A340-500/600	320	1010
A380	400	1260

Single-Engine Taxi-Out. The Airbus Flight Crew Operating Manual (FCOM) includes supplementary procedures for Single Engine Taxi Out (SETO), which are recommended by Airbus for departing aircrafts. Nevertheless, pilots should be aware of the associated risks when conducting SETO and apply Threat and Error Management[18] (TEM) practices accordingly. On an A320 aircraft with only one engine running, greater thrust may be required, leading to potential risks such as jet blast and foreign object damage. As engine starting takes time and attention, it is crucial to ensure situational awareness and checklist compliance are not compromised. Flight crew members should communicate clearly regarding the timing and location of the remaining engine start to avoid startling one another. Additionally, in busy areas, ATC should be informed when increasing thrust to confirm that no ground personnel are nearby. Engines also require warm-up time, and therefore, should be started with sufficient time before take-off. SETO can be hindered by various factors such as upslopes, steep curves, or congested ramps, so the crew must be vigilant for ground crew and aircraft, while also listening carefully to ATC. Furthermore, multitasking and time pressure during SETO increase the risk of errors.

Despite these considerations, single engine taxi can reduce CO_2 emissions during the taxi phase. Although the CO_2 savings may seem minimal on an individual flight basis, fleet-wide implementation of SETO can lead to significant benefits. As Table 9 below demonstrates, a saving of 4 kg of fuel can be achieved per minute on an A320.

Table 9.

Single engine taxi fuel and CO_2 emissions savings per minute. Source (Airbus-WIN, 2023, Win Series 2023:EP4 Single Engine Taxi-Out).



Savings per Sector	Fuel (kg/min)	CO_2 (kg/min)
A300-600	10	31
A320ceo	4	12
A330-200	10	31
A340-300	5	15

Climb. The Computerized Flight Plan[19] (CFP) must be consistent with aircraft performance and it is vital to continuously monitor the aircraft performance to keep CFP predictions as close as possible.

Reduced flap[20] setting: The goal is to ensure that the aircraft's performance is predicted as accurately as possible. Although the lowest flap setting produces the least amount of drag and therefore results in the lowest fuel burn, other considerations such as

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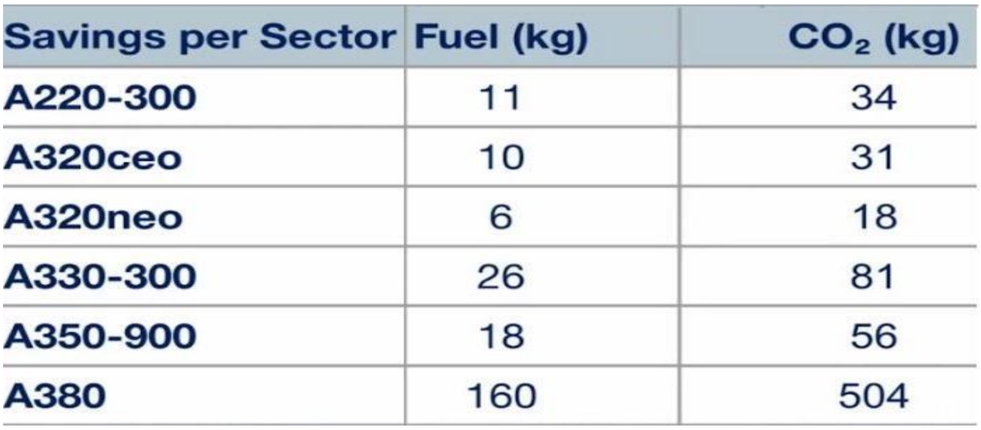
[18] Threat and Error Management (TEM) is an aviation approach that focuses on proactively identifying and addressing potential threats and errors to enhance safety during flight operations. It involves recognizing and analyzing factors that could negatively impact operations and taking measures to mitigate their impact.

[19] A Computerized Flight Plan is a detailed document, created by a computer program that guides the aircraft from its origin to its destination. It includes details such as the route, altitude, speed and fuel consumption required for the journey. The plan can be adjusted by the pilot or air traffic control as needed during the flight.

[20] Flaps and slats are parts of an airplane's wings that can be extended to change the shape and surface area of the wing. By extending these surfaces, the airplane can generate more lift at lower speeds, this is crucial during take-off and landing. This allows the airplane to fly more safely and efficiently. On an A320 the sequence flap setting from lowest to highest is: O, CONF 1, CONF 1+F, CONF 2, CONF 3 and CONF FULL.

maximizing take-off weight, take-off speeds, or noise abatement may require higher flap settings. Thus, the appropriate flap setting should be selected for each departure instead of using the same configuration systematically. Table 10 displays the fuel savings and CO_2 emission reductions achieved by using configuration (CONF) 1 + F for take-off instead of CONF 3. It is important to strike the right balance between performance, noise, and fuel consumption when selecting the take-off configuration.

Table 10.
Fuel and CO_2 emissions savings using CONF 1+F instead of CONF 3 per flight. Source (Airbus-WIN, 2023, Win Series 2023:EP5 Climb).



Savings per Sector	Fuel (kg)	CO_2 (kg)
A220-300	11	34
A320ceo	10	31
A320neo	6	18
A330-300	26	81
A350-900	18	56
A380	160	504

Flexible Take-Off[21] (Flex T/O) versus Take-Off/Go Around[22] (TOGA) thrust: Reduced thrust or flexible take-off is a technique that optimizes thrust based on the aircraft weight, runway, and ambient conditions. The benefits of operating the engines at lower thrust include extending engine life and reducing maintenance costs for the airline. On dry and wet runways, flexible take-off is the recommended method for take-off at reduced thrust. The highest flex temperature[23] is typically achieved at the lowest flap setting. However, it is important to note that using flex take-off increases fuel consumption compared to using TOGA thrust. Thus, the optimal balance between maintenance cost reduction, fuel consumption, and CO_2 emissions must be found based on operational constraints. During flight planning initialization, the flight crew can input climb wind values for different flight levels. Accurate wind data must be entered for each phase of flight in order to achieve the best predictions. During climb, the FMS computes fuel and time predictions as well as Economic (ECON) speed mark targets using the forecast wind data. The climb efficiency improves with greater wind data accuracy. The FMS flight plan takes into account the 250 knots speed limitation below 10,000 feet by default. If permitted by ATC, the crew may remove this limitation to accelerate to the optimum ECON climb speed, resulting in cost savings, reduced fuel consumption and CO_2 emissions. Figure 5 below displays an example

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[21] Flexible Take-off (Flex T/O) is a take-off procedure where the engine thrust is set to a lower level than maximum, based on the current outside conditions, to reduce wear on the engines and save fuel.

[22] Take-Off/Go Around (TOGA) thrust is a maximum engine power setting used in aviation during take-off and go-around maneuvers, A go-around maneuver is a standard aviation procedure performed by pilots during an aborted landing.

[23] Modern jet engines may generate more thrust than is generally needed for take-off, therefore flex temperature takes advantage of this. It helps extend the engine's life and lessen wear and tear by lowering the temperature at which the engine runs.

of the theoretical take-off climb profile that would produce the best performance and fuel consumption results to achieve greater efficiency and reach the top of the climb earlier.

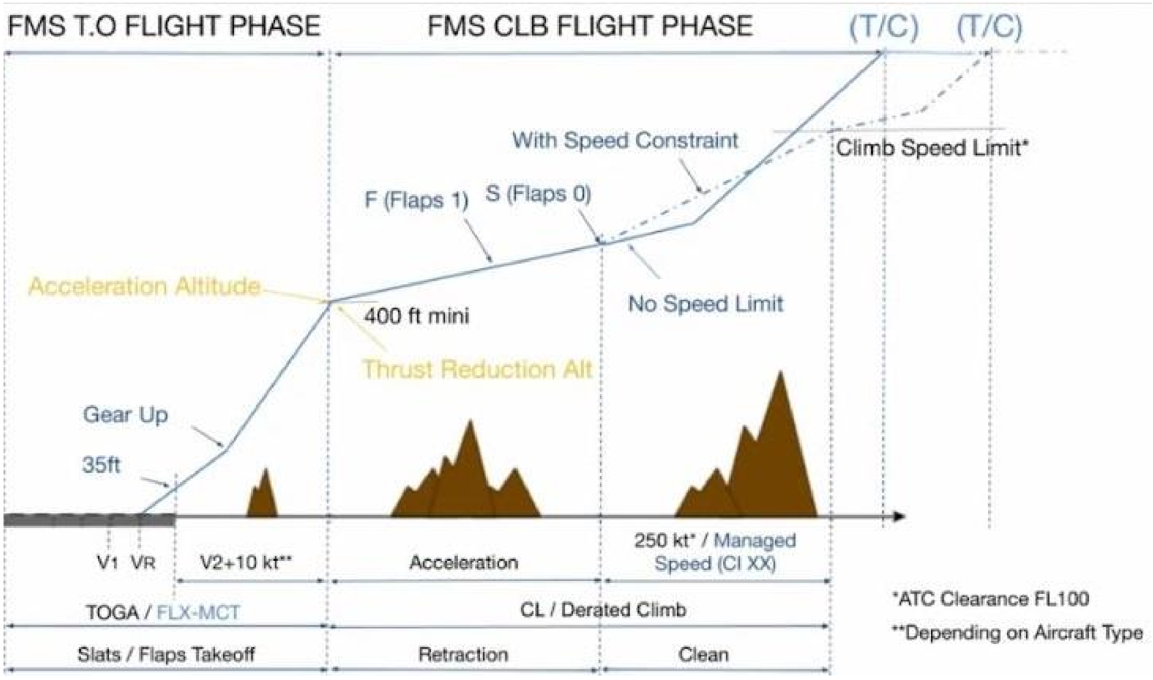

Figure 5. Optimum Take-off/Climb profile with and without speed constraint. Source (Airbus-WIN, 2023, Win Series 2023:EP5 Climb).

Cruise. Flying at the appropriate speed and at the most efficient flight level is crucial to optimize aircraft performance during the cruise phase. This phase commences upon reaching the designated cruise level and engaging ALT CRZ[24] mode in an Airbus aircraft. Cruise phase ends when the aircraft initiates the descent and approaches a distance of 200 nautical miles from the destination. The FMS calculates the optimal speed based on the performance factor and CI. To ensure optimal performance, the flight crew should engage the managed[25] speed modes. For instance, on an A320 aircraft, a slight increase in Mach number of 0.01 can cause up to 2.6% more fuel consumption (Airbus-WIN, 2023), resulting in increased CO_2 emissions. Similarly, the FMS determines the most economical flight level for a given CI, accounting for aircraft weight, temperature, and winds. As the aircraft loses weight during the flight because of fuel consumption, the optimal flight level continually updates and changes. It is crucial for the flight crew to fly as close as possible to the optimal flight level and to monitor it regularly. In some cases, if altitude changes are challenging to achieve, it may be advantageous to request an initial cruise altitude above the optimal flight level. To ensure accurate results, the flight crew must input the latest weather data, including wind and temperature for four different flight levels (A320 FCOM), to reflect the actual wind and temperature profile. Table 11 below demonstrates the penalties incurred when flying below the optimal flight level, for Single Aisle (SA) and Twin Aisle (TA) aircraft.

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[24] ALT CRZ is an automatic feature on Airbus aircraft, when engaged it adjusts the aircraft's cruising altitude during a flight to optimize fuel consumption and make the flight more efficient.

[25] Managed speed refers to the automated speed control system on an aircraft, whereby the aircraft's speed is governed and adjusted by the FMS instead of the pilot's own selection.

Table 11.
Fuel and CO_2 emissions penalties flying 2000 ft below optimum flight level per flight. Source (Airbus-WIN, 2023, Win Series 2023:EP6 Cruise).

Savings per Flight	Fuel (kg)	Fuel (%)	CO_2 (kg)
Single Aisle (A220/A320)	170	1.2	530
Twin Aisle (A330/A350)	850	1.2	2 680

Descent. During the descent preparation phase, if the landing conditions, aircraft performance permit, and air traffic flow allow, the flight crew may request the ATC to assign a runway that minimizes the approach or taxi time, or both, thus reducing the overall taxi and flight time, similar to the take-off phase. To ensure an optimal approach, the flight crew should maintain a clean configuration and manage the configuration for the approach phase. The FMS computes the most economical descent profile by providing the managed speed. Unless otherwise restricted by ATC, the flight crew should use the managed speed to achieve the optimum economic speed during the descent. The FMS calculates the vertical profile for the descent by using the aircraft weight, entered CI, and aircraft performance from the performance database, computed backward from the threshold. The managed descent in traditional FMS calculations is conservative and not steep enough, with wide margins. However, the flight crew can reduce these margins to optimize the descent profile by accurately inserting wind data in the FMS. It is important to note that the use of ANTI-ICE systems increases fuel consumption and associated CO_2 emissions, and should only be used when necessary without compromising safety. For instance, avoiding the use of wing and engine anti-ice systems between 10,000 and 1,500 feet can result in significant CO_2 savings, as shown in Table 12 below.

Table 12.
Fuel and CO_2 emissions savings not using ANTI ICE from 10,000 ft to 1,500 ft per flight. Source (Airbus-WIN, 2023, Win Series 2023:EP7 Descent).

	Fuel (kg)	CO_2 (kg)
A320ceo	20 to 30	60 to 95
A320neo	10 to 15	30 to 45
A330ceo	50 to 70	155 to 220
A330neo	120 to 140	375 to 440
A340-300	60 to 70	190 to 220

Holding and Approach. In order to minimize fuel consumption and associated CO_2 emissions, flight crews should avoid holding patterns, unless instructed by the ATC. However, in the event that holding cannot be avoided, there are two variables that can be adjusted to achieve fuel savings: flap configuration and speed. Keeping the aircraft in an aerodynamically clean configuration and deploying landing gear and flaps only when necessary will reduce drag and fuel consumption. Therefore, maintaining a clean configuration is optimal throughout the flight. When in a clean configuration, the flight crew should fly at the Green Dot[26] speed. Decelerated approach, where the aircraft is configured for landing step by step and reaches final landing configuration at about 1,500 ft AGL, instead of fully configuring before the Final Approach Fix[27] (FAF) or Final Descent Point (FDP), can also save fuel during the approach. Continuous descent approach, which eliminates the deceleration level off, reduces the time the aircraft stays at level flight altitude, thereby reducing fuel consumption.

Landing with flaps in CONF 3/idle reverse[28]/autobrake LOW will make the aircraft more aerodynamically efficient, resulting in fuel savings. However, CONF 3 landing in conflict means more deceleration energy to stop the aircraft, potentially leading to a longer landing distance. The use of idle reverse instead of full reverse can also reduce fuel consumption and be beneficial for the engine, but may increase the landing distance and should only be used when performance permits. Flight crews should keep in mind the phenomenon of brake oxidation, which occurs when brakes reach high temperatures multiple times, leading to the degradation of carbon material and a loss of its strength. To extend the life of brakes, the use of autobrake at landing is recommended by Airbus. Backtracking the runway and making a U-turn at the end of the runway should be avoided to save fuel. Table 13 provides data that illustrates the fuel savings associated with certain landing configurations, specifically CONF 3 versus CONF FULL and reverse idle and full reverse.

It is important to strike the right balance between performance and fuel consumption when selecting the landing configuration. A visual[29] approach procedure can also lead to significant fuel savings, reducing up to 945 kilograms of CO_2 or 300 kilograms of fuel per approach compared with the standard instrument approach (Airbus-WIN, 2023).

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[26] Green Dot Speed denotes a particular airspeed that offers the optimal lift-to-drag ratio for an aircraft, allowing for the most fuel-efficient flight. In essence, it represents the speed at which an aircraft can fly with maximum efficiency.

[27] FAF or FDP is a designated point in the sky where pilots begin their final descent to an airport's runway. It marks the start of the final segment of the approach, where the aircraft is lined up with the runway and begins to descend at a steeper angle towards landing. Pilots typically configure the aircraft for landing at the FAF and continue to monitor its speed, altitude, and direction until it touches down on the runway.

[28] The use of the reverse thrust system assists the pilot in slowing and stopping the aircraft after landing, thus generating a forceful braking force. It is a crucial safety feature that facilitates pilot control of their aircraft on the runway.

[29] A visual approach is a landing approach where the pilot navigates and lands the aircraft visually, without relying on instrument guidance, when weather conditions are favorable. It allows for a more efficient and direct approach to the runway using visual cues such as the airport runway and surrounding terrain.

Table 13.
Fuel savings per flight utilizing different CONF for landing and reverse. Source (Airbus-WIN, 2023, Win Series 2023:EP8 Holding and Approach).

Aircraft Type	CONF 3 VS. CONF FULL	REV IDLE VS. REV MAX	REV IDLE/CONF 3 VS. REV MAX/CONF FULL
A300/A310	15 to 30	30 to 65	50 to 80
A320	10 to 15	10 to 20	20 to 40
A330	10 to 25	25 to 60	40 to 75
A340-200/300	15 to 20	35 to 40	50 to 60
A340-500/600	10 to 15	65 to 90	75 to 95
A380	30	40 to 50	20 to 80

Single-Engine Taxi-In. Single-Engine Taxi-In (SETI) provides similar benefits as SETO, but additional measures can be taken during taxiing to reduce fuel consumption and CO_2 emissions. These include taxiing with one or both packs turned off, delaying the start of the APU, or avoiding APU start altogether if a Ground Power Unit[30] (GPU) available upon arrival at the gate may contribute to brake savings, lower APU and engine maintenance, enabling not only fuel saving but also reduce ground noise. Stettler et al., (2018) conducted a research study on SETI and SETO, which revealed that a reduction of 0.3% in the total ground-level NO_X, 4.3% reduction in total ground-level Carbon Monoxide (CO), and 3.6% reduction in total ground-level HydroCarbon (HC) emissions could potentially result in significant savings.

The Use of Sustainable Aviation Fuel

To comprehend the advantages of SAF, the authors will provide a concise explanation of the ramification of traditional jet fuel and its environmental impact.

Emissions from the Combustion of Jet Fuel

The combustion of jet fuel releases greenhouse gases and, under some circumstances, forms contrails, also called AIC. According to the FAA Office of Environment and Energy (2015), approximately 90% of aircraft emissions occur between the altitudes between 3,000 feet and 43,000 feet above the ground, with the remaining ten percent emitted during taxi, take-off, initial climb, and during the approach and landing. The emissions explained in FAA Office of Environment and Energy (2015), includes CO_2, water vapor, nitrogen oxides, hydrocarbon, carbon monoxide, sulfur oxides, and soot particulates. The largest component of the emissions is CO_2 which is approximately 70% of the exhausts.

- The CO_2 is the product of complete combustion of traditional jet fuel.
- Water vapor is the product of the hydrogen in the fuel combined with the oxygen in the air. This is the source of the condensation trails.
- Nitrogen oxides are the product in high pressure combustion when air passes through high temperatures.

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[30] GPU provides electrical power to an aircraft while parked with the engines and APU turned off. The GPU is connected to the aircraft through a cable, supplying power to the electrical systems.

- Hydrocarbons emitted from incomplete fuel combustion which contributes to the formation of ground-level ozone.
- Carbon monoxide is formed due to the incomplete combustion of the carbon in the fuel and contributes to the formation of ozone.
- Sulfur oxides are produced from petroleum fuels where sulfur is present and in combination with oxygen from the air during combustion.
- Small particles of soot form as a result of incomplete combustion and aerosols from condensed gases.

The FAA Office of Environment and Energy (2015) explains that aircraft is not the only source of emissions produced within the aviation sector. Other contributing factors to the emissions are, for example, ground support vehicles, traffic to and from the airport such as shuttle buses, ground support equipment, and the APU.

Contrails - Aircraft-Induced Clouds

AIC are also called condensational trails. AIC are clouds generated by the aircraft's exhaust. They are composed of water vapor that condenses on soot particles and due to the low temperatures form ice crystals that create condensational trails. The AIC is, therefore, artificial clouds of ice crystals induced behind the aircraft (Sherry & Thompson, 2020).

Figure 6 illustrates three distinct forms of AIC, namely short-lived contrails, long-lived persistent contrails, and long-lived contrail cirrus. The short-lived contrail duration is less than ten minutes, and are line-shaped and have short duration because of the atmospheric condition that does not sustain contrails. The long-lived contrails are persistent and cirrus contrails. The persistent contrails can be as long as ten kilometers, remain line-shaped, and remain as long as ten hours. The cirrus contrail is when the persistent trails lose their line-shaped formation and transform into contrail cirrus with irregular shapes. These contrails can merge with other contrails in traffic-congested areas or merge with natural cirrus clouds.

Figure 6. (a) short-lived contrails, (b) long-lived persistent contrails, (c) long-lived contrail cirrus. Source (Sherry & Thompson, 2020).

AIC has a cooling effect on global warming by reflecting sunlight back into space and reducing the amount of infrared radiation that is emitted from the Earth's surface. "This imbalance affects the temperature structure in the lower atmosphere, therefore, contributing to global warming." (Sherry & Thompson, 2020, p. 828). The study indicates that AIC contributes 55% of aviation's total contribution to global warming and CO_2 with 39%. The effect of the AIC is immediate and short-term, it is lost as soon as the AIC dissipates, and the CO_2 can persist for up to 20 years (Sherry & Thompson, 2020).

What is SAF?

SAF is, according to BP (2022), fuel produced from sustainable feedstock and is very similar in its chemistry to traditional fossil jet fuel produced by fossil feedstock. ICAO (2016) explains that the first generation is produced from crops which could be subject to additional concerns of sustainability such as the use of land to use the fields to produce fuel instead of food. Current technology of producing SAF allows the use of municipal waste, used cooking oil, and agricultural residues. The report from Cabrera & Melo de Sousa, (2022) describes that most of the production of SAF is from plants, and the associated carbon life cycle emissions can significantly be reduced. Some of the CO_2 will be reabsorbed by the next generation of crops, see Figure 7. The feedstock also allows the production of SAF to be closer to the airport which minimizes the cost and the emissions of transportation. To be considered SAF, ICAO (2016) explains that the fuel must meet sustainability requirements set by ICAO as part of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). CORSIA is a global market-based measure for harmonized national cooperation to reduce emissions and minimize the distortion of the market while respecting the special circumstances and respective capabilities of the ICAO member states (IATA, 2016).

The use of SAF is in an early stage, and the EASA European Aviation Environmental Report (2022) reports that the current supply of SAF is as low as 0.05% of the total use of Europe Union aviation fuel. However, during the conference Fossilfritt Flyg I NORRA SVERIGE it was mentioned that several companies had announced their intention to enter the SAF market by 2030, and the existing producers announced a significant capacity increase. For instance, Norwegian air shuttle and Norsk e-fuel made a partnership to build the first full-scale electrofuel factory to produce sustainable fuel in the Norwegian state Mosjøen (Norwegian, 2023).

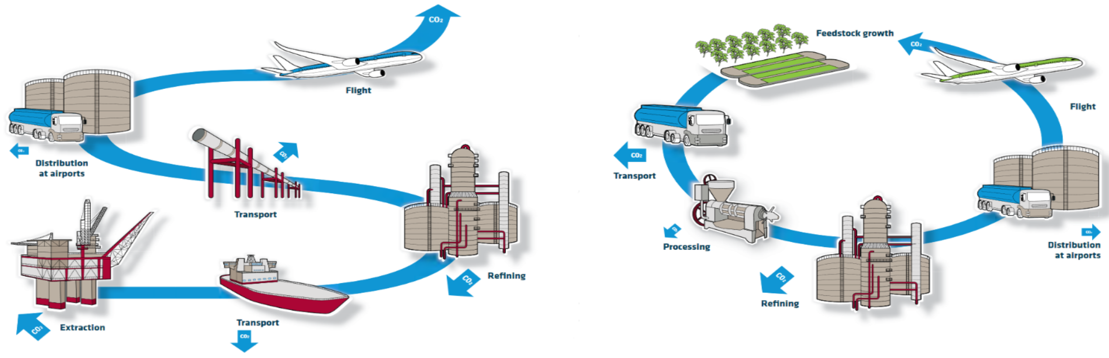


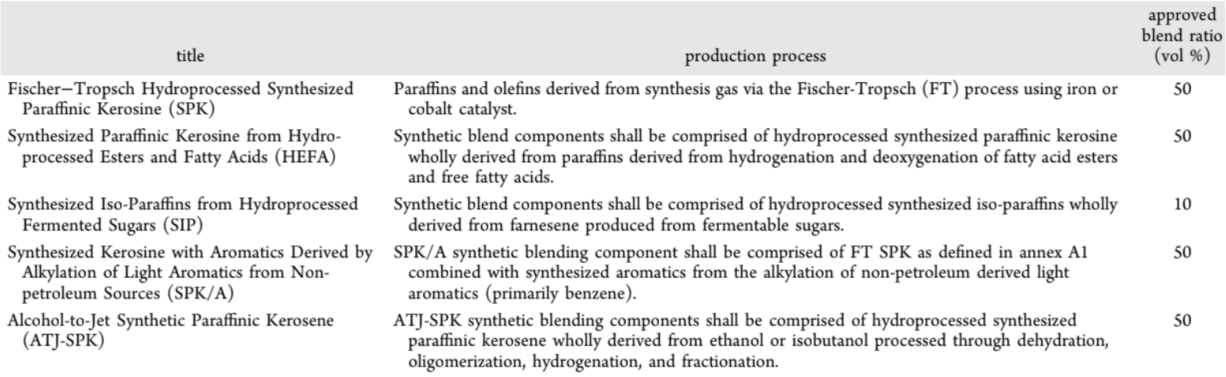
Figure 7. Carbon life cycle diagram. Traditional jet fuel to the left, SAF to the right. Source (Cabrera & de Sousa, 2022).

Fuel Composition. According to (ICAO, 2022), the commercial aviation industry has strict safety standards for fuel in operation, and for maintenance of its equipment. The most widely used standard for Jet A1 fuel (traditional jet fuel) has requirements for composition such as volatility, fluidity, corrosion, combustion, thermal stability, materials compatibility, and other factors. Aircrafts are often refueled in different states, and the national standards for jet fuel differ. Therefore, a concept of fuel “drop-in” was introduced to mix traditional jet fuel from different sources. The drop-in method is therefore of the most importance in implementing SAF and reducing the impact on the environment.

SAF can be blended with traditional jet fuel up to a certain percentage and is certified for use in the existing fleet, requiring no changes to the aircraft, engine or infrastructure. However, there are challenges that concern feedstocks for producing drop-in fuels. Many sustainable feedstocks such as vegetable oils, animal fats, and waste oils are also used in other industries such as food and chemical production. The production process for SAF is currently more expensive than traditional fossil fuels. Technical challenges associated with blending drop-in fuels with conventional fuel. Some of the SAF have different chemical properties than traditional aviation fuel that could affect engine performance or require modifications to fuel systems (Sman et al., 2021).

The aircraft engines that are certified to use the aviation fuel Jet A1 are also approved to use SAF via the method of drop-in fuel. Drop-in method means that SAF can be used in a mix with traditional jet fuel such as Jet A1. The approved blending ratio depends on the type of SAF. According to Vozka et al., (2019) some of the types of SAF are approved with a ratio of up to 50%, see Table 14. The requirement in the drop-in method is essential because a drop-in with SAF does not need to be handled separately from other aviation fuel. This also reduces the cost by using the already implemented infrastructure of the fuel distribution.

Table 14.
SAF blending ratio for different types of SAF. Source (Vozka et al., 2019).



title	production process	approved blend ratio (vol %)
Fischer−Tropsch Hydroprocessed Synthesized Paraffinic Kerosine (SPK)	Paraffins and olefins derived from synthesis gas via the Fischer-Tropsch (FT) process using iron or cobalt catalyst.	50
Synthesized Paraffinic Kerosine from Hydroprocessed Esters and Fatty Acids (HEFA)	Synthetic blend components shall be comprised of hydroprocessed synthesized paraffinic kerosine wholly derived from paraffins derived from hydrogenation and deoxygenation of fatty acid esters and free fatty acids.	50
Synthesized Iso-Paraffins from Hydroprocessed Fermented Sugars (SIP)	Synthetic blend components shall be comprised of hydroprocessed synthesized iso-paraffins wholly derived from farnesene produced from fermentable sugars.	10
Synthesized Kerosine with Aromatics Derived by Alkylation of Light Aromatics from Non-petroleum Sources (SPK/A)	SPK/A synthetic blending component shall be comprised of FT SPK as defined in annex A1 combined with synthesized aromatics from the alkylation of non-petroleum derived light aromatics (primarily benzene).	50
Alcohol-to-Jet Synthetic Paraffinic Kerosene (ATJ-SPK)	ATJ-SPK synthetic blending components shall be comprised of hydroprocessed synthesized paraffinic kerosene wholly derived from ethanol or isobutanol processed through dehydration, oligomerization, hydrogenation, and fractionation.	50

Life Cycle of SAF. By using SAF, CO_2 emissions can be reduced by up to 80% of its life cycle (Cabrera & de Sousa, 2022). The life cycle of SAF involves several stages, feedstock, conversion to fuel, distribution to airports, distribution to aircraft, and the combustion of the fuel in the aircraft. According to (EPA, 2022) the first step in producing SAF is to source the feedstocks. The feedstock can be from different sources for example agricultural waste, forestry residues, municipal waste, algae, and dedicated energy crops. The second step is to use the feedstocks to extract the energy-rich molecules that will form the basis of the fuel. Once the feedstocks are collected, they undergo a series of chemical processes to convert them into aviation fuel. After the fuel is produced, it is transported to the airports.

When the SAF is transported to the airports, it is used in aircraft in combination with traditional fossil fuels through the concept of drop-in fuel. SAF can be used in existing aircraft without requiring any modifications, and it provides similar chemical performance characteristics to traditional jet fuel. Finally, when the fuel is used, the remaining waste is via recycling or safe disposal. Most of the CO_2 emissions produced in the combustion are then reabsorbed by the next generation of feedstock. SAF is considered to be a more sustainable fuel option because it can be produced from renewable feedstocks, and its use results in lower greenhouse gas emissions compared to traditional jet fuel. The life cycle of sustainable aviation fuel is designed to reduce the environmental impact of aviation by providing a more sustainable fuel option for the aviation industry.

AIC Effects in the Use of SAF. Contrails form as the water vapor and soot particles that are emitted by the engine at high altitudes and condenses into droplets or ice crystals forming AIC. Therefore the particles generated in the combustion, such as soot, influence the formation of contrails. Sman et al. (2021) explain that the lower aromatic and sulfur content in SAF can lead to differences in contrail and cirrus formation. The use of SAF generates less soot, and it can potentially reduce the formation of contrails. As explained by Sherry & Thompson (2020) by using SAF with the method of drop-in fuel, the soot emissions can reduce soot count by 50%. However, Sherry & Thompson (2020) further explains that longer-term solutions that require investment in research and development, design and certification costs, and deployment costs include improved aerodynamics and engine design to reduce soot emissions, Liquid Natural Gas (LNG) and Liquid Hydrogen (LH_2) engines or both, and fuel additives to modify ice crystal properties or suppress ice crystal formation.

By operational changes, AIC can be reduced and can slow global warming and buy time for longer-term CO_2 initiatives to take effect. Adapting the cruise flight levels to reduce the time in areas with atmospheric conditions for AIC generation is the most practical and low-cost near-term mitigation option (Sherry & Thompson, 2020).

Advancements in Aircraft and Engine Technology

In the fleet efficiency improvement section, there are two parts: Investing in new aircraft and engines or retrofitting[31] with new enhancements to improve the existing aircraft. The authors have chosen Airbus for this study, other manufacturers are offering various solutions to improve the efficiency of the existing fleet and the study will present some of Airbus solutions.

New Aircraft and Engines

The new generation of aircraft, meaning an aircraft that is available for purchase or lease today for an airline, is estimated to save fuel from 14 up to nearly 48% compared to their predecessors, see Table 15 (Sman et al., 2021). The improvements done to the A320 New Engine Option (NEO) family, have led to saving about 20% per seat fuel burn than the previous engine choice Classic Engine Option (CEO). The respective savings per Available Seat Kilometer[32] (ASK) are 19%, 20% and 23% for the A319, A320 and A321 (Sman et al., 2021). The newer aircrafts are made with the use of lighter materials. For instance, around 70% of cutting-edge materials, including composites, titanium and contemporary aluminum

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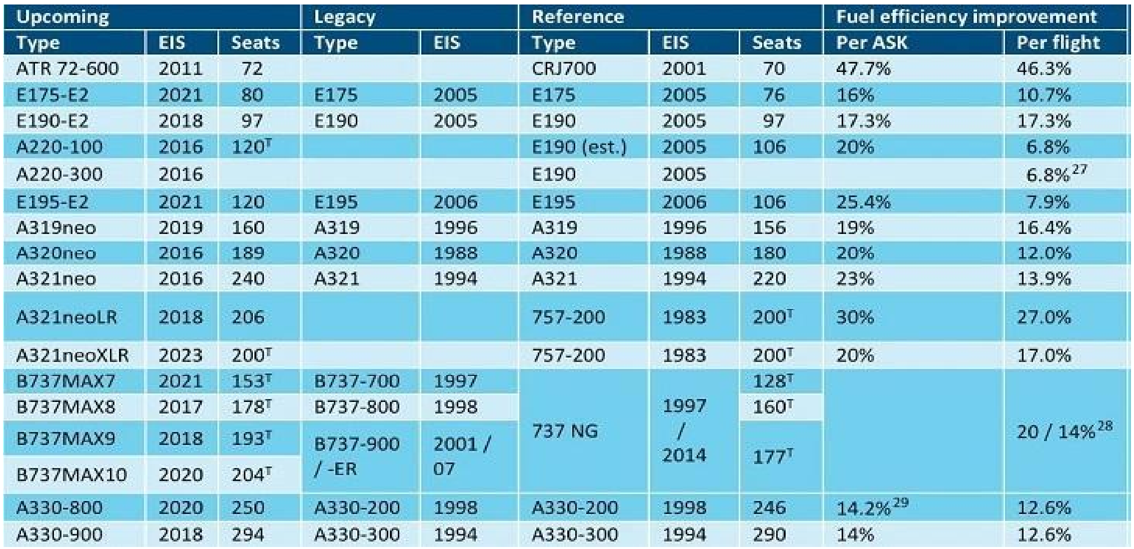
[31] Is the process of updating or modifying an existing aircraft with newer or improved equipment or technology.

[32] Available Seat Kilometer (ASK) is a way that airlines measure how many passengers they carry over a certain distance. Calculated by multiplying the number of available seats on a flight by the distance in kilometers the flight travels. ASK aids airlines determine how well they utilize their planes and resources, and plan new routes or adjust prices.

alloys are used in the A350's aircraft body to create a lighter, more fuel-efficient aircraft. The use of these materials contributes to improving corrosion resistance and lowers the requirement for maintenance on the aircraft as well according to Airbus.

Table 15.
Fuel efficiency improvement potential and entry into service of upcoming aircraft and types, relative to reference type. Source (Sman et al., 2021).



Upcoming			Legacy		Reference			Fuel efficiency improvement	
Type	EIS	Seats	Type	EIS	Type	EIS	Seats	Per ASK	Per flight
ATR 72-600	2011	72			CRJ700	2001	70	47.7%	46.3%
E175-E2	2021	80	E175	2005	E175	2005	76	16%	10.7%
E190-E2	2018	97	E190	2005	E190	2005	97	17.3%	17.3%
A220-100	2016	120^{T}			E190 (est.)	2005	106	20%	6.8%
A220-300	2016				E190	2005			6.8%[27]
E195-E2	2021	120	E195	2006	E195	2006	106	25.4%	7.9%
A319neo	2019	160	A319	1996	A319	1996	156	19%	16.4%
A320neo	2016	189	A320	1988	A320	1988	180	20%	12.0%
A321neo	2016	240	A321	1994	A321	1994	220	23%	13.9%
A321neoLR	2018	206			757-200	1983	200^{T}	30%	27.0%
A321neoXLR	2023	200^{T}			757-200	1983	200^{T}	20%	17.0%
B737MAX7	2021	153^{T}	B737-700	1997	737 NG	1997 / 2014	128^{T}		20 / 14%[28]
B737MAX8	2017	178^{T}	B737-800	1998			160^{T}		
B737MAX9	2018	193^{T}	B737-900 / -ER	2001 / 07			177^{T}		
B737MAX10	2020	204^{T}							
A330-800	2020	250	A330-200	1998	A330-200	1998	246	14.2%[29]	12.6%
A330-900	2018	294	A330-300	1994	A330-300	1994	290	14%	12.6%

As of 2018 an A320 NEO price starts at approximately $110.6 million USD, while the list price for a new A320 CEO is approximately $101.0 million USD depending on the design weights, engines choice and level of selected customization (Airbus, 2018). However, airlines typically negotiate significant discounts off the list price and the actual purchase price of an aircraft can be much lower than the list price. Additionally, prices are subject to change over time, due to factors such as currency fluctuations and market demand. As a result, airlines often opt to lease aircraft as a means of avoiding a significant upfront investment. An illustrative example of the leasing prices as of 2021 is presented in Table 16. Based on a study conducted by Sman et al., (2021), it has been determined that the average lifespan of an aircraft before it is decommissioned and substituted with a new one is 22.5 years.

Table 16.
Average new aircraft lease rates worldwide in 2021, in thousands US dollars per month. Source (Statista, 2023).

Retrofit

Anti-Condensation. Condensation presents a significant challenge for aircraft due to its potential to accumulate in different areas, including aircraft insulation blankets and electrical systems, which contributes to excess weight. This additional weight can lead to increased fuel consumption and maintenance expenses and can also decrease the aircraft's payload capacity. One way airlines can address this issue is by implementing technologies such as Anti-Fuselage-Condensation to reduce moisture-related problems and improve their operations. CTT[33] systems is a well-known Swedish company that specializes in developing and producing products related to humidity control inside aircraft. Various airlines have conducted dedicated trials and recorded a weight loss of 200-300 kg in SA aircrafts after two to three months of moisture-protected operations. Additionally, there is documented evidence of a 40% reduction in unscheduled electrical component changes per 1,000 flight hours for airlines that have implemented this technology (CTT Systems, 2023). Non-condensing airplanes are inherently lighter and experience fewer moisture-related issues, such as the need to replace or repair insulation blankets and electrical systems.

Airbus (2023c) categorizes the retrofit upgrades into three different sections: The path optimizers, the material upgrades and the resource managers.

The Path Optimisers. Descent Profile Optimisation (DPO), a fuel-saving software modification, is available for A320 CEO and A330 CEO aircraft. For an A320 and an A330, respectively, this modification can reduce fuel consumption by up to 75 kg and 140 kg per descent, saving up to 140 tonnes of fuel and 441 tonnes of CO_2 annually. In order to achieve its goals, DPO modifies the FMS to decrease margins during approach and descent, enabling a later top of descent and a shorter deceleration distance at level-off. The upgrade is completed in just four hours.

Idle Factor Optimizer (IFO), developed by NAVBLUE[34], that complements the DPO software. IFO uses data analytics to compute the optimized Idle factor for individual aircraft by decoding and analyzing data over three months, recomputing aircraft-specific Idle Factors, and ingesting them into the FMS. This allows for continuous adjustment of the FMS prediction of the descent trajectory, resulting in fully optimized descents for each aircraft when combined with DPO. The IFO can minimize the use of air brakes and thrust increase during descent, leading to potential fuel savings of up to 59 tonnes and CO_2 savings of 184 tonnes per aircraft per year.

Required Navigation Performance Authorization Required[35] (RNP AR) that can be applied to all Airbus aircraft families, enabling the use of satellite positioning systems for flying RNP AR procedures. The RNP AR procedure offers benefits such as reduced fuel consumption, shorter flight time, flexible and more direct flight paths, noise footprint management, and increased airspace capacity by saving track miles. NAVBLUE provides comprehensive support to airlines throughout the entire process, including stakeholder management, pilot training, and operational approval.

The Material Upgrades. Sharklets are retrofit devices that can be installed on many A320 CEO family aircraft, as these are standard on the NEO. These devices are attached to the wing tips of the aircraft, effectively increasing the wing span and reducing lift-induced

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[33] CTT stands for the founders of the company Christer, Tom and Thomas.

[34] NAVBLUE is a subsidiary of Airbus that provides digital solutions for the aviation industry. They specialize in flight operations, navigation systems and aeronautical data management. Their software tools and services help airlines and operators optimize their flight planning, enhance navigation accuracy and improve operational efficiency.

[35] RNP AR following a particular path can help the pilots save time, fuel and noise. The pilots employ GPS and other cutting-edge navigation equipment onboard.

drag. Sharklets can provide fuel savings of at least four percent, which results in a decrease in CO_2 emissions. Additionally, they improve the aircraft's take-off, climb, and initial cruise altitude performance, as well as its range and payload.

Single Engine Taxi Without APU (SETWA), an upgrade available for A320 CEO. On the older CEO, the APU has to be started in order to perform SET so this upgrade will allow the aircraft to taxi without starting the APU and takes approximately eight hours to install. After installation, the aircraft can save up to 91 tonnes of fuel and 290 tonnes of CO_2 per year according to Airbus. The upgrade not only delivers fuel savings but also reduces ground noise and lowers engine and APU maintenance costs as earlier mentioned.

The Resource Managers. Smartfill, a Skywise[36] store application designed specifically for airlines operating the A350, which determines the optimal amount of potable water needed for each flight. By analyzing previous flights and customizing the risk level, Smartfill accurately calculates the exact amount of water required for the upcoming flight, thus reducing the risk of overloading the aircraft. Loading less than the maximum capacity of potable water reduces the weight of the aircraft, which in turn, reduces fuel burn. Overall, Smartfill helps airlines to optimize their potable water loading process and improve the fuel efficiency of their A350 operations.

Air Management Function (AMF), an upgrade which can save up to 115 tons of fuel and 363 tons of CO_2 per aircraft per year according to Airbus. The upgrade can be installed within six hours. AMF works by adjusting the mix of conditioned fresh air taken from engine or APU bleed with recirculated air filtered by High Efficiency Particle Arrestor (HEPA) filters, based on the number of passengers entered in the FMS. Without AMF, the air conditioning system is designed to accommodate high-density layouts, but with AMF, the amount of fresh air, or "bleed demand," is optimized according to the number of passengers on board, potentially reducing fuel burn in cases of lower density layouts and/or low load factor. This is similar to the A320 pack flow low selection. However, this can bring more precise and efficient savings.

New Upcoming Technology

New technologies have potential to make a substantial difference in different classes. A study conducted by Sman et al., (2021) calculated the proportion of CO_2 emissions in 2018 for each class of airplanes. Table 17 presents the results indicating that Small (S) and Regional (R) aircraft emissions were nearly insignificant in comparison to other categories.

Table 17.

Aircraft classes and share of 2018 ASKs and CO_2 emission. Source (Sman et al., 2021).

Class (abbreviation)	**Seating capacity**	**Example(s)**	**Share of 2018 ASKs**	**Share of 2018 CO_2 emissions**
Small (S)	0 – 19		0.01%	0.02%
Regional (R)	20 – 100	ATR42, ATR72, Embraer E175	2.99%	3.78%
Single aisle (SA)	101 – 240	Airbus A320 family, Boeing 737	56.4%	51.6%
Small/medium twin aisle (SMTA)	241 – 350	Airbus A330, Boeing 787	27.8%	30.3%
Large twin aisle (LTA)	351 +	Airbus A350, Boeing 777	12.8%	14.3%
Total			**100%**	**100%**

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[36] Skywise is an aircraft option powered by the expertise of Airbus and Palantir Technologies, a leading provider of data analytics. It integrates in-flight, engineering and operational data within a robust analytical environment.

A study conducted by Lundahl & Lindqvist (2020) found that electric-powered aircraft have the potential to reduce environmental impact by a factor of 6-15 when compared to fossil fuel-powered counterparts. According to Sman et al., (2021) study, electric-powered aircraft have entered the market for small aircraft. However, for categories SA and larger, battery technology and capacity prevent completely electric aircraft for these categories. New technologies may make such aircraft possible in the future. Nonetheless, this process is expected to take a considerable amount of time. Hybrid-electric aircraft powered by hydrogen are expected to be introduced for the R categories in 2028 made by the Swedish company Heart Aerospace (2023). The ES-30 will carry up to 30 passengers with a maximum range up to 800 km.

Airbus is currently developing the Zero-emission (ZEROe) project (Airbus, 2023d), which aims to launch aircraft with hydrogen fuel into service by 2035. The project includes three types of aircraft, namely turbofan, turboprop and blended-wing body, capable of carrying up to 200 passengers on flights of up to 3700 km, which could potentially benefit the SA and R categories.

Airbus is currently engaged in a project related to “hybridisation” (Airbus, 2023e), which involves utilizing different energy sources during the flight, either simultaneously or consecutively. This concept combines jet fuel or SAF with electricity to enhance overall energy efficiency and reduce fuel consumption. Through hybridization, energy management is improved, resulting in a significant reduction of up to five percent in fuel usage compared to regular flights. Electrical sources may derive from either batteries or fuel cells, which can convert hydrogen into electricity. In November 2022, Airbus made an announcement regarding its fuel cell-powered engine as part of this project.

Hydrogen Sustainable Aviation Fuel. Hydrogen (H_2) is a type of SAF. According to McKinsey & Company (2020), hydrogen can be used in either gas or liquid form for aircraft to power jet engines or hydrogen gas in fuel cells that convert the hydrogen gas into electricity to power electrical engines.

The production of hydrogen gas is according to Khalilpour (2019) by using electrolysis by splitting water molecules into hydrogen and oxygen. By using renewable electricity the production of hydrogen gas can be done as a sustainable process. When using hydrogen as fuel, the combustion exhaust is pure water. Hydrogen fuel has the potential to significantly reduce greenhouse gas emissions from the aviation industry, Sman et al. (2021) states that the production and use of hydrogen face technical and economic challenges. There is also an energy demanding process to go from gas to liquid hydrogen, which should also be generated using sustainable sources.

The challenges for the use of hydrogen as aviation fuel are according to Sman et al. (2021), the technical and economic challenges associated with scaling up production and distribution infrastructure. One challenge is that the current infrastructure for producing, storing, and transporting hydrogen is limited, and would need to be significantly expanded to support the use of hydrogen as a fuel for aviation. This would require significant investment in new infrastructure, such as pipelines, storage tanks, and refueling stations. Another challenge is that hydrogen has a low energy density compared to traditional fossil fuels. This means that more space is required to store the same amount of energy in the form of hydrogen fuel or shorter routes to be flown.

Discussion

The purpose of this study was to evlauate different literatures and find strategies airlines may employ in order to reduce their environmental impact, particularly their fuel consumption which leads to reduced CO_2 emissions and reduced environmental impact. Table 17 highlights that most of the environmental emissions of aviation belong to the category SA and larger operators. This study may offer a structured approach for airlines to take practical steps towards achieving sustainability objectives. Moreover, the study can contribute to increasing consciousness about the significance of sustainability and stimulating a greater number of airlines to engage in this quest.

The study that was conducted illustrates three distinct timelines: the present, near future, and future.

- Present: pertains to actions that can be promptly implemented at no or relatively low cost.
- Near future: pertains to investments and actions that may be made within the span of five to ten years.
- Future: pertains to investments that are considered to be long-term, with a timeframe ranging from 20 to 25 years ahead.

Airline operations are fundamentally driven by cost considerations, and long-term investment decisions, such as aircraft acquisitions that require careful evaluation.

Present

According to Figure 1, presented by Belobaba et al. (2009), fuel costs account for roughly 30 percent of an airline's operating expenses. It is reasonable to presume that airline management would support the first pillar mentioned, which is efficient ground and aircraft operations, given that this expense represents a significant portion of the airline's expenditures; it would yield the most considerable financial benefit when compared to other expenses incurred by an airline. By promoting fuel-efficient practices among pilots, immediate and substantial reductions in fuel consumption and emissions could be achieved without requiring a substantial investment in equipment. However, while implementing efficient fuel-saving procedures is essential, crew motivation is a critical factor in their successful adoption. Unless the crew is suitably incentivized and motivated to adhere to these procedures, the desired cost savings may not be realized. The successful implementation of fuel saving procedures requires the involvement of top management and a commitment to encourage compliance throughout all levels of the organization, similar to the implementation of a just culture[37]. While visual approaches and fuel-saving procedures can help reduce costs, they can also increase pressure and stress on pilots during landing and potentially lead to additional work such as reports or go-arounds. As a result, some pilots may not see the appeal of these procedures since the personal benefits may be minimal. It is worth noting that in addition to the factors mentioned earlier, some airlines pay their pilots based on the number of hours flown. Therefore, flying faster and reducing the flight time may result in less compensation to the pilots, while benefiting the airlines by allowing them to utilize the pilots for more working days in a year without increasing their salary. Hence, the primary

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[37] Just Culture is a concept used in aviation safety management systems to create an environment where the crew feel comfortable reporting safety concerns without fear of punishment from management.

advantage of shorter flight times is typically accrued by the company rather than the pilot. Incentives beyond the potential reduction in fuel costs may be necessary to motivate pilots to engage in these practices. It would be advisable to consider offering incentives, such as bonuses or kickbacks, to crew members who demonstrate a commitment to implementing green operating procedures. To ensure maximum engagement, it is recommended that incentives are offered at an individual level. It is important to note that the distribution of bonuses to all crew members, regardless of their participation in fuel and emission savings, may not be an effective motivator. To encourage participation from all crew members, it may be beneficial to announce bonuses paid to those who make additional contributions to fuel and emission savings. In order to maintain confidentiality, it is crucial to ensure that personal data and identities of participating crew members are protected.

The subject of sustainability and fuel efficiency came up during an interview with a manager at a smaller airline, see Appendix 1. The manager responded that their business does not place a high priority on fuel savings at all when questioned about their strategy. This is partly because the customer, not the business, pays for the cost of the fuel. Instead, the company's top priority is making sure that its clients arrive at their destination on time and safely. For this reason, regardless of the weather, the company always includes a minimum of 500 kilograms of fuel in their flight plans. This is done to reduce the possibility of detours brought on by insufficient fuel, which would ultimately cost the company additional expense and less profit. Nevertheless, this business model is not commonly observed in the aviation industry where fuel costs constitute a significant portion of an airline's operational expenses (Belobaba et al., 2009), making fuel savings a crucial consideration.

With respect to fuel policy, the authors are cognizant of the sensitivity of this issue among pilots. As per regulations, the decision on the amount of fuel to be carried is entirely at the discretion of the commander, with minimum regulatory requirements in place. Nevertheless, based on their personal experience flying with various companies, the authors have observed that many pilots tend to carry excess fuel, which is not necessary. As mentioned in the previous paragraph, Appendix 2 from a smaller company showed that despite the extra 500 kg, the crew still added extra fuel on top. This behavior stems from a variety of reasons, and one of the authors has noticed from own experience that pilots often carry extra fuel due to a lack of understanding of the requirements and for their own comfort rather than any actual need for the extra fuel. It is imperative that airlines allocate resources towards adequate training programs to ensure that pilots are well-versed with fuel requirements. Moreover, airlines should provide regular reminders to pilots on fuel requirements and present evidence-based data that demonstrates the safety of adhering to fuel requirements. Additionally, airlines should encourage their pilots to abstain from carrying unnecessary extra fuel.

The Airbus-WIN program (2023) includes nine phases that propose various methods to reduce fuel consumption and fuel penalties. The pilot's decision-making and flight management may save a substantial quantity of fuel and reduce emissions. In one instance, a flight could potentially save 550 kg of fuel by achieving a short taxi and departure from the departing airport, followed by a visual short approach into the arriving airport. This objective may be difficult to achieve due to the volume of incoming traffic at an airport, but Table 18 illustrates an alternative approach. Pilots could implement the majority of these techniques to save up to 180 kg of fuel per flight. A savings of 180 kg per flight, four times a day, every day of the year, can add up to a significant sum, especially for an airline with a large aircraft fleet and numerous flights.

Table 18.
Example of potential savings on flight from A-B applying some of the efficient ground and flight operations. Source (Data collected and calculated from Airbus-WIN (2023) as reference.

Item	**Savings (kg/flight)**
SETO 5 minutes of taxi	-20 kg
Start APU 5 minutes before departure instead of 15[38]	-22 kg
CONF 1+F instead CONF 3	-10 kg
CONF 3 /reverse idle versus CONF FULL/ full reverse	-40 kg
SETI 5 minutes of taxi	-20 kg
No APU start at arrival[39]	-65 kg
The total potential savings per flight	-177 kg

The CI is a critical metric in airline operations, calculated as the ratio of the time-related cost of airplane operation to fuel cost. Despite its apparent simplicity, various factors such as fluctuating fuel prices across operating locations, fuel-tankering, and fuel hedging can complicate the CI calculation, leading to unfair competition. To ensure equitable application of the CI, such complexities must be taken into account. A slight extension of flight time for each flight would have a negligible impact on the passenger experience. However, the cost and emission savings resulting from correct CI over the course of a year would be of considerable significance.

Near Future

SAF is the most mature alternative energy source for aviation, even if electric battery technology and hydrogen airplanes are developing at a fast pace. The use of SAF is allowed to be used up to 50% as drop-in fuel up until today's date. Electric batteries and hydrogen have a low energy density, and they will need more innovations/improvements to be replaced as energy sources.

The utilization of SAF has the potential to reduce AIC effects by reducing the warming impact generated by contrails and cirrus clouds (Sherry & Thompson, 2020). Nonetheless, additional investigation is requisite to comprehensively ascertain the consequences of SAF on contrail formation and its possible advantages.

The availability of SAF is one of the main obstacles to the adoption of alternative fuels. Although there has been a lot of progress in the creation of SAF generated from algae and plant matter, there is still a lack of infrastructure that is crucial in order to support the use of SAF. The cost of SAF, which at the moment is more expensive than fossil fuels, is another huge obstacle. Nonetheless, it is expected that their use will expand as production increases and the price of SAF falls.

There are limited areas where the airline can directly exert control and therefore, it is crucial to utilize available resources in the most efficient manner possible. While a switch to

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[38] This can present a challenge during hot summer days, thus it would be beneficial to have external air conditioning facilities accessible at the airport.

[39] By not starting the APU the starting cycles are reduced, which in turn, aids in reducing APU maintenance cost additionally to saving fuel.

SAF might be a desirable option, it is not yet readily available everywhere and can be prohibitively expensive, leading to competitiveness challenges. Consequently, one way to achieve the desired efficiency gains is to optimize fleet and operation through fuel-saving strategies, as previously suggested.

Future

The profitability of investing in new airplanes is contingent on several factors, including the level of utilization, prevailing fuel prices and the business model adopted. According to the interviewed manager from the smaller airline, investing in new future fuel-saving technologies is not his primary concern as the client bears the fuel cost, and his focus is on reducing the operational expenses of the airline. Therefore, such business models do not find investing in new future fuel-saving technologies particularly appealing or prioritized.

According to Sman et al. (2021), the typical operational lifespan of an aircraft is 22.5 years. Therefore, investing in an aircraft entails a long-term commitment. Replacing an airline's fleet could yield fuel savings up to 48% depending on the aircraft type (Sman et al., 2021). However, the economic feasibility of fleet replacement hinges on the airline's specific business model. In instances where such replacement is not cost-effective, retrofitting presents a viable option for effecting smaller, yet notable improvements. Particularly for airlines with larger fleets, retrofitting can significantly reduce fuel costs and positively impact overall expenses which leads to reduced environmental emissions.

Given the imminent advent of numerous new technologies and advancements in the market, an airline may not find it alluring to invest in currently available aircraft for purchase. Considering the long-term implications of such investments, it may be preferable to opt for aircraft leasing. Nevertheless, it is noteworthy that the airline stands to enjoy more favorable terms and lease rates with an extended leasing contract. Thus, the airline ought to consider its business model before making such a commitment.

The research found that electrical aircraft can have economic and environmental benefits within smaller aircrafts but with large aircrafts and for long routes the best option is still the traditional propulsion system that uses Jet A1 with the possibility to use SAF with the drop-in concept to reduce the CO_2.

Impact the Airlines Can Make

Certain factors are beyond the control of airlines, such as regulations, fuel prices, SAF production, and advancements in technology. Nevertheless, they can indirectly influence aircraft design by demonstrating interest in SAF development and exhibiting a willingness to incorporate SAF into their operations. Additionally, airlines can impact the emissions originating from service equipment. For instance, ground vehicles that contribute to overall aviation emissions. To that end, airlines can select service suppliers that utilize eco-friendly equipment, such as electric cars or buses, to help mitigate the effects of these emissions.

As previously stated, a company's inclination towards implementing sustainable practices is influenced by its business model. Imposing mandatory emission reduction policies globally through legislation and regulations would prevent unfair competition.

Nevertheless, developing countries with weak economies may be disinclined to raise costs for their populace. Hence, the issue cannot be resolved through simplistic solutions.

In the aviation industry greenwashing not only misleads consumers but also hinders efforts to reduce the industry's environmental impact. It can also lead to a lack of transparency, making it difficult for the consumers to determine if the airline is authentically committed to sustainability. To counteract greenwashing in the aviation industry, it is essential for businesses to adopt more sustainable practices and disclose their environmental impact. Before making purchases, consumers can also play a vital role by conducting research on the sustainability efforts of companies. Finally, regulatory bodies should continue to impose and enforce stringent environmental standards to prevent companies from engaging in greenwashing.

Conclusion

There are a number of obstacles to overcome in order to establish a sustainable airline. Some minor steps can be taken today by airlines, but for a greater impact on the environment, more research is required to develop alternative energy sources to propel aircrafts in the future, including how aircrafts will be designed to carry these new energy sources.

The airline's business model may influence its willingness to adapt to become more sustainable. However, It should be noted that fuel savings, emission reduction, and cost savings are interlinked and go hand in hand, making it easier to motivate the majority of airlines to implement efficient ground and aircraft operations. Therefore, with appropriate crew motivation the airline can immediately reduce their carbon footprint without making significant investments.

To compel airlines to use SAF in order to reduce CO_2 emissions, global regulations must be modified. However, prior to adoption by airlines, it is necessary that the availability and affordability of SAF is ensured.

Motivating the continued use of a procedure requires motivation, education, and information, such as monetary incentives or evidence-based data demonstrating the effect of applicable procedure modifications.

Final Recommendations

It is essential to incentivize and motivate pilots to adhere to fuel-efficient procedures, as their cooperation is crucial in achieving fuel and cost savings. Offering individual-level incentives, such as bonuses or kickbacks, could help encourage pilots to participate actively in green operating procedures. Airlines should allocate resources towards adequate training programs and provide regular reminders to pilots on fuel requirements, encouraging them to abstain from carrying unnecessary extra fuel.

In near future more research is needed on the effects of AIC, cheaper methods for producing SAF and the effects on the engines with increased blending ratio with the use of SAF in traditional jet fuel. We need to go from 50 percent to 100 percent SAF

An airline should aim to aid sustainability research, by sharing raw data and be open for feedback from researchers regarding areas of improvement. Additionally, the airline should provide financial contributions and commit to utilizing upcoming potential technology.

References

Airbus. (2004, October). Getting to grips with fuel economy. *Flight Operations Support & Line Assistance*. https://ansperformance.eu/library/airbus-fuel-economy.pdf

Airbus. (2018, January 15). *2018 price adjustment across Airbus' modern product range reflects continuous investment and customer value*. Airbus. Retrieved April 16, 2023, from https://www.airbus.com/sites/g/files/jlcbta136/files/2021-07/new-airbus-list-prices-2018.pdf

Airbus. (2021, December 1). *EN-Airbus-A380-Facts-and-Figures-Dec-2021*. Airbus. Retrieved April 16, 2023, from https://www.airbus.com/sites/g/files/jlcbta136/files/2021-12/EN-Airbus-A380-Facts-and-Figures-December-2021_0.pdf

Airbus. (2022, November 30). *Airbus reveals hydrogen-powered zero-emission engine*. Airbus. Retrieved April 16, 2023, from https://www.airbus.com/en/newsroom/press-releases/2022-11-airbus-reveals-hydrogen-powered-zero-emission-engine

Airbus. (2023a). *A340-600*. Airbus. Retrieved April 16, 2023, from https://www.airbus.com/en/who-we-are/company-history/commercial-aircraft-history/previous-generation-aircraft/a340-family/a340-600

Airbus. (2023b). *A350-900 | A350 | Aircraft*. Airbus Aircraft. Retrieved April 16, 2023, from https://aircraft.airbus.com/en/aircraft/a350-clean-sheet-clean-start/a350-900

Airbus. (2023). *FCOM* [Flight Crew Operating Manual].

Airbus. (2023c). *Fuel Efficiency Solutions*. Airbus Aircraft. Retrieved April 16, 2023, from https://aircraft.airbus.com/en/services/enhance/systems-and-airframe-upgrades/fuel-efficiency-solutions#setwa

Airbus. (2023d). *ZEROe - Zero emission*. Airbus. Retrieved April 16, 2023, from https://www.airbus.com/en/innovation/zero-emission-journey/hydrogen/zeroe

Airbus. (2023e, March 4). *Hybrid and electric flight*. Airbus. Retrieved April 16, 2023, from https://www.airbus.com/en/innovation/zero-emission-journey/hybrid-and-electric-flight

Airbus-WIN. (2023, January). *WIN Series*. WorldWide Instructor News – FLIGHT OPERATIONS SUPPORT AND TRAINING STANDARDS. Retrieved April 16, 2023, from https://www.airbus-win.com/

Alquezar, R. D., & Macedo, R. H. (2019, October-December). Perspectives in Ecology and Conservation. *Airport noise and wildlife conservation: What are we missing?*, *17*(4), 163-171. https://doi.org/10.1016/j.pecon.2019.08.003

Backman, J. (2016). *Rapporter och uppsatser* (3rd ed.). Studentlitteratur.

Belobaba, P., Barnhart, C., & Odoni, A. (Eds.). (2009). *The Global Airline Industry*. Wiley. http://komaristaya.ru/stud/the.global.airline.industry.pdf

BP. (2022, June). *What is sustainable aviation fuel (SAF) and why is it important? | News and views | Air bp*. BP. Retrieved April 16, 2023, from https://www.bp.com/en/global/air-bp/news-and-views/views/what-is-sustainable-aviation-fuel-saf-and-why-is-it-important.html

Brundtland, G. H. (1987). *Our Common Future: Report of the World Commission on Environment and Development*. Sustainable Development Knowledge Platform. Retrieved April 16, 2023, from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Cabrera, E., & Melo de Sousa, J. M. (2022). Use of Sustainable Fuels in Aviation—A Review. *Energies*, *15*(7), 2440. https://doi.org/10.3390/en15072440

CTT Systems. (2023). *Anti-Condensation*. CTT Systems. Retrieved April 16, 2023, from https://www.ctt.se/anti-condensation/

EASA. (2022, September). *Executive Summary and Recommendations*. EASA. Retrieved April 17, 2023, from https://www.easa.europa.eu/eco/sites/default/files/2022-09/EnvironmentalReport_EASA_summary_12.pdf

EASA. (2023, January 30). *Easy Access Rules for Large Aeroplanes (CS-25) - Revision from January 2023*. EASA. Retrieved April 16, 2023, from https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-large-aeroplanes-cs-25?page=6#_DxCrossRefBm548991130

EPA. (2022, December 16). *Lifecycle Analysis of Greenhouse Gas Emissions under the Renewable Fuel Standard | US EPA*. Environmental Protection Agency. Retrieved April 16, 2023, from https://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel#prod_distribution

FAA. (2015). *Aviation Emissions, Impacts & Mitigation: A Primer, January 2015*. Federal Aviation Administration. Retrieved April 16, 2023, from https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/primer_jan2015.pdf

Harrocks, L., & McMurchie, J. (2022, October 28). *The truth about f(lying): greenwashing in the aviation industry*￼. Aviation Environment Federation. Retrieved April 23, 2023, from https://www.aef.org.uk/2022/10/28/the-truth-about-flying-greenwashing-in-the-aviation-industry/

Heart Aerospace. (2023). *ES-30*. Heart Aerospace. Retrieved April 16, 2023, from https://heartaerospace.com/es-30/

IATA. (2016). *Factsheet: CORSIA*. IATA. Retrieved April 17, 2023, from https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---corsia/

ICAO. (2016). *CO_2 ROAD-MAP*. Sustainable Aviation. Retrieved April 16, 2023, from https://www.sustainableaviation.co.uk/wp-content/uploads/2018/06/FINAL__SA_Roadmap_2016.pdf

ICAO. (2022, October 7). *INNOVATION FOR A GREEN TRANSITION*. ICAO. Retrieved April 16, 2023, from https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2022/ICAO%20ENV%20Report%202022%20F4.pdf

ICAO. (2022, November 28). *ICAO document - CORSIA Sustainability Criteria for CORSIA Eligible Fuels*. ICAO. Retrieved April 17, 2023, from https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2005%20-%20Sustainability%20Criteria%20-%20November%202022.pdf

IEA. (2022). *Aviation – Analysis*. IEA. Retrieved April 16, 2023, from https://www.iea.org/reports/aviation

IPCC. (2014). *AR5 Climate Change 2014: Mitigation of Climate Change — IPCC*. IPCC. Retrieved April 16, 2023, from https://www.ipcc.ch/report/ar5/wg3/

Khalilpour, K. R. (2019). Chapter 5 - Interconnected Electricity and Natural Gas Supply Chains: The Roles of Power to Gas and Gas to Power. In *Polygeneration with*

Polystorage: For Chemical and Energy Hubs (pp. 133-155). Elsevier Science. https://doi.org/10.1016/B978-0-12-813306-4.00005-7

Lundahl, J., & Lindqvist, P. (2020). Livscykeljämförelse av klimatpåverkan från elektriskt och fossilbränsledrivna flygplan på tre svenska inrikesrutter. *KTH – Skolan för Industriell Teknik och Management*. http://www.diva-portal.se/smash/get/diva2:1438056/FULLTEXT01.pdf

McKinsey & Company. (2020, July 22). Hydrogen Powered Aviation: A Fact-based Study of Hydrogen Technology, Economics, and Climate Impact by 2050. *Clean Sky 2 JU; FCH 2 JU*. https://cleansky.paddlecms.net/sites/default/files/2021-10/20200507_Hydrogen-Powered-Aviation-report.pdf

Norwegian. (2023, April 24). *Norwegian och Norsk e-Fuel ingår samarbete för att bygga elektrobränslefabrik*. Press Release. Retrieved April 24, 2023, from https://media.se.norwegian.com/pressreleases/norwegian-och-norsk-e-fuel-ingaar-samarbete-foer-att-bygga-elektrobraenslefabrik-3247931

Roberson, B. (2007). Fuel conservation strategies. *Aero*, *Q2*, 24-26. Retrieved April 16, 2023, fromhttps://www.boeing.com/commercial/aeromagazine/articles/qtr_2_07/AERO_Q207_article5.pdf

Sherry, L., & Thompson, T. (2020). Primer on Aircraft Induced Clouds and Their Global Warming Mitigation Options. *Transportation Research Record*, *2674*(11), 827-841. https://doi.org/10.1177/0361198120951188

Sman, E. V. d., Peerlings, B., Kos, J., Lieshout, R., & Boonekamp, T. (2021, February). *NLR-CR-2020-510*. Destination 2050. Retrieved April 16, 2023, from https://reports.nlr.nl/server/api/core/bitstreams/c9002b7e-224f-420c-b6da-ab6aecd48ea2/content

Statista. (2023, March 23). *Average aircraft monthly lease rates 2021*. Statista. Retrieved April 16, 2023, from https://www.statista.com/statistics/1258900/aircraft-lease-rates-aircraft-model/

Stettler, M., Koudis, G., Hu, S., Majumdar, A., & Ochieng, W. (2018, December). The impact of single engine taxiing on aircraft fuel consumption and pollutant emissions. *The Aeronautical Journal*, *122*(1258), 1967-1984. https://doi:10.1017/aer.2018.117

Vozka, P., Vrtiška, D., Šimáček, P., & Kilaz, G. (2019, March 6). Impact of Alternative Fuel Blending Components on Fuel Composition and Properties in Blends with Jet A. *Energy & Fuels*, *33*(4), 3275-3289. https://pubs.acs.org/doi/10.1021/acs.energyfuels.9b00105

WHO. (2016). *Ambient air pollution: A global assessment of exposure and burden of disease*. World Health Organization (WHO). Retrieved April 16, 2023, from https://www.who.int/publications/i/item/978924151135

Appendix 1

Interview with management from a small ACMI[40] company that does not want to be named.

Question asked to the management	**Answers from management**
To what extent does your company prioritize sustainability in terms of fuel policy and reduction of emission, and what measures have been implemented to uphold this commitment?	Our business model is such that the client is paying for the fuel so in our company that is not a priority, on the contrary we always carry extra fuel of 500 kg no matter the weather conditions just to be on the conservative side.
What would it take for you to implement such measures to reduce emission on fuel?	Well, if the client insists and demands it from us then we will have to implement such measures but our network is not built for detours so it is better to improve the chance of arriving at our destination than to risk a possible detour.
Would it not be advantageous from a competitive standpoint for your company to exhibit superior fuel management and consumption compared to your clients or other competing entities in the market?	Sure that is a good point. However, for the moment our business model has no need for that, and by investing in those solutions I have to invest time and money in something that will reduce the profit of the company.
Is the airline interested in investing in new future fuel saving technologies and aircraft?	The most important factor for us is the lease cost of the aircraft, the newest aircraft with latest technology are the most expensive and as mentioned fuel savings are not our primary concern. However, if the leasing prices were the same then yes.
Could we please have access to some fuel data from your company so that we can see how much fuel is uplifted by the pilots versus the planned fuel.	Yes, you can use this for the study, but I would request that the name of the company is not provided in your essay anywhere in the essay.

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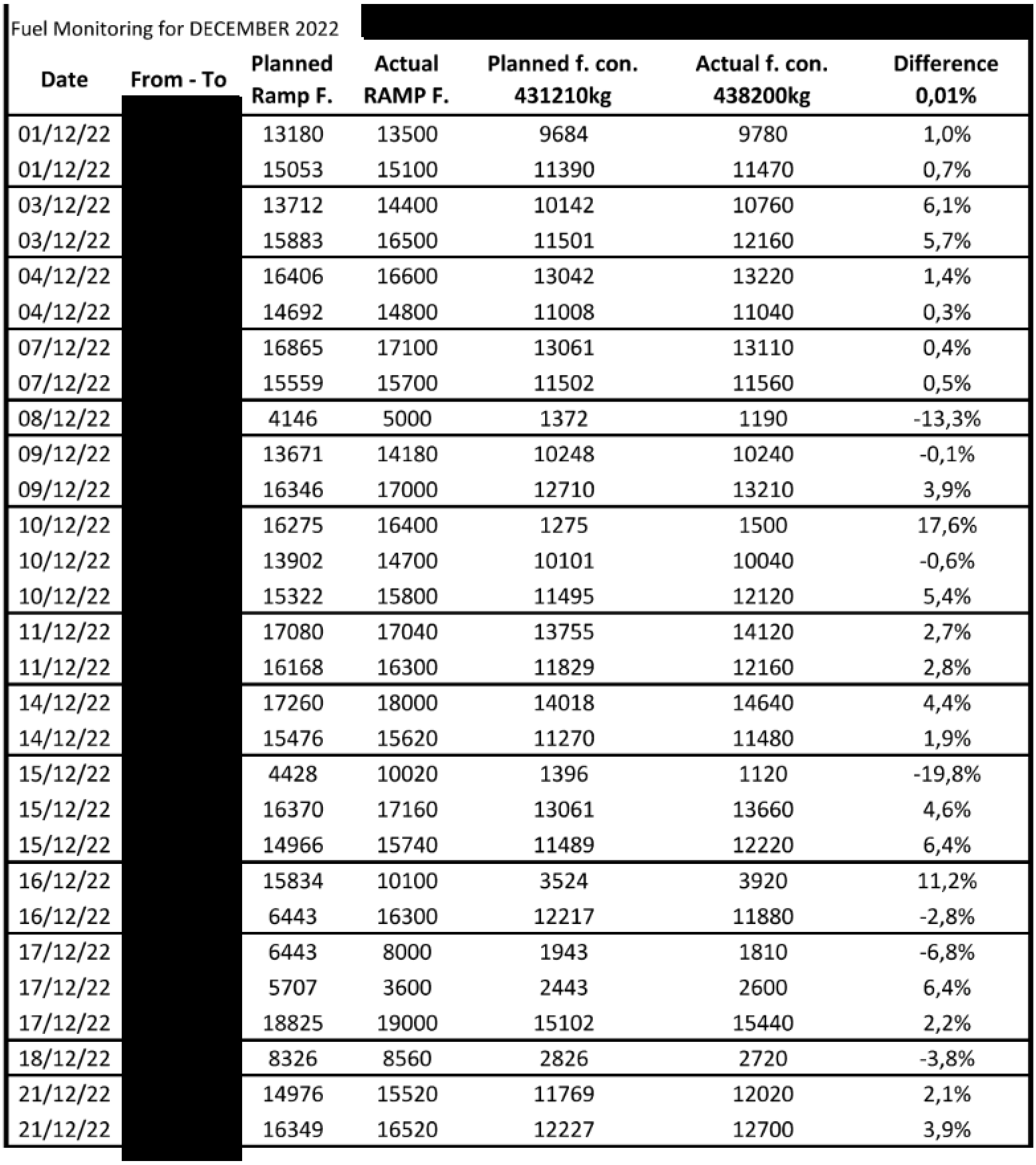
[40] Aircraft Crew Maintenance and Insurance (ACMI) is a company used by other airlines to supplement their fleet during peak season or in case of short notice requirements.

Appendix 2

Fuel data from the smaller company for December 2022, planned ramp fuel is done by the CFP and actual ramp fuel is what the pilots decide to take. The difference column is the difference between planned consumption versus actual consumption.



Fuel Monitoring for DECEMBER 2022 [redacted]

Date	From - To	Planned Ramp F.	Actual RAMP F.	Planned f. con. 431210kg	Actual f. con. 438200kg	Difference 0,01%
01/12/22	[redacted]	13180	13500	9684	9780	1,0%
01/12/22	[redacted]	15053	15100	11390	11470	0,7%
03/12/22	[redacted]	13712	14400	10142	10760	6,1%
03/12/22	[redacted]	15883	16500	11501	12160	5,7%
04/12/22	[redacted]	16406	16600	13042	13220	1,4%
04/12/22	[redacted]	14692	14800	11008	11040	0,3%
07/12/22	[redacted]	16865	17100	13061	13110	0,4%
07/12/22	[redacted]	15559	15700	11502	11560	0,5%
08/12/22	[redacted]	4146	5000	1372	1190	-13,3%
09/12/22	[redacted]	13671	14180	10248	10240	-0,1%
09/12/22	[redacted]	16346	17000	12710	13210	3,9%
10/12/22	[redacted]	16275	16400	1275	1500	17,6%
10/12/22	[redacted]	13902	14700	10101	10040	-0,6%
10/12/22	[redacted]	15322	15800	11495	12120	5,4%
11/12/22	[redacted]	17080	17040	13755	14120	2,7%
11/12/22	[redacted]	16168	16300	11829	12160	2,8%
14/12/22	[redacted]	17260	18000	14018	14640	4,4%
14/12/22	[redacted]	15476	15620	11270	11480	1,9%
15/12/22	[redacted]	4428	10020	1396	1120	-19,8%
15/12/22	[redacted]	16370	17160	13061	13660	4,6%
15/12/22	[redacted]	14966	15740	11489	12220	6,4%
16/12/22	[redacted]	15834	10100	3524	3920	11,2%
16/12/22	[redacted]	6443	16300	12217	11880	-2,8%
17/12/22	[redacted]	6443	8000	1943	1810	-6,8%
17/12/22	[redacted]	5707	3600	2443	2600	6,4%
17/12/22	[redacted]	18825	19000	15102	15440	2,2%
18/12/22	[redacted]	8326	8560	2826	2720	-3,8%
21/12/22	[redacted]	14976	15520	11769	12020	2,1%
21/12/22	[redacted]	16349	16520	12227	12700	3,9%