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Sustainability in Aviation Industry

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Abstract- Air travel has become an extremely important factor to our global society, because it is theprimary force behind global social, economic and cultural growth around the world. Approximately 3% of the world's CO2 emissions are now produced by the aviation industry,with jet fuel consumption accounting for the majority of these emissions. However, improving the sustainability of air travel is not that easy. Lifting people and objects into the air and transporting them over great distances requires a lot of energy. On that account, our mini project will be dealing with the actions that airlines can take to lower their environmental impact by incorporating sustainability into every aspect of the regular tasks. This paper reviews the ways to improve the aviation's long-term viability by emphasising onattaining sustainable aviation fuel and also by looking at new materials and coating technologies to make planes lighter and more aerodynamic. Furthermore, explore the challenges of introducing Operational improvements – on the ground, during departure and arrival and also in cruise. Additionally, in the last part of our study we have researched someapproaches of different airlines through case studies and thrown light into failed theories to support our discussion.

Keywords- Sustainability, Aviation, Fuel efficiency, Carbon dioxide emissions, aircraftoperations.

I. INTRODUCTION

The aviation industry is vital to the evolution of our global civilization. It has completely transformed how we travel, communicate with people, and conduct business. Without aircraft, it would be difficult to imagine our global community. The actual cost of flying has decreased by 60% over the past 40 years due to the democratization of international aviation, making it more accessible and inexpensive for many people. Around the same time interval, aircrafts have increased in fuel efficiency by 70% and have also become 75% quieter. Many sectors worldwide would be envious of such a track record. But because we approximate that by 2030 the number of international and domestic passengers will reach a total of six billion, traveling on approximately fifty million flights, which would be roughly twice the amount as in 2011, so we know that more must be done.

Although Aviation industry is relatively very small, it has a disproportionately huge impact on our climate system. The ICCT estimates that one of the sources of greenhouse gases with the greatest rate of growth is air travel, which contributes to around 3% of global carbon emissions. As per Nikita Pavlenko, a senior fuels researcher at ICCT, "the least-emitting flight is one that doesn't happen at all."

Throughout the history of aviation, the challenge of decreasing the fuel consumption of aircrafts has been the main drive for research and technical development. Several airlines have announced numerous initiatives to try and improve their sustainability during the future years. Recently, Delta Air Lines pledged $1 billion to achieve carbon neutrality by 2030. In a similar vein, United Airlines and JetBlue both promised to arrive by 2050. Similar promises have been made by a number of other international airlines.

Table 1. Climate action framework - Short term goal.

Short-term Goal
From 2009 through 2020, there was an average annual increase in fuel efficiency of 1.5%.
Progress
With a 2% improvement, progress is currently far over target.
How is the industry achieving this?
Introducing new technology: switching out older aircraft for more newer, effective ones.

However, improving sustainability in aviation is complicated than we think. It takes enormous energy to travel long distances carrying cargo and people. The aviation industry has developed many measures to minimize the fuel consumption. The most significant of these is moving from conventional jet fuels that are manufactured from fossil fuels to those made from

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renewable sources and those with reduced production emissions. In order to make their aircrafts lighter and more aerodynamic, airlines are also looking for newer materials and coating technologies.

The aviation industry adopted the world's first worldwide, sector-wide climate action framework in 2008. Goals for the short, medium, and long term form the framework.

Table 2. Climate action framework - Medium term goal.

Medium-term Goal
Carbon-neutral growth to maintain net aircraft CO_2 emissions at 2020 levels.
Progress
implementation of a global offset programme CORSIA
How is the industry achieving this?
It will be necessary to implement market-based measures to offset any emissions that the aviation sector is unable to eliminate through technological, operational, or infrastructure Improvements or by using sustainable aviation fuels.

Table 3. Climate action framework - Long term goal.

Long-term Goal
Reducing net CO_2 emissions to half what they were in 2005 by the year 2050.
Progress
Significant research is being done.
How is the industry achieving this?
Sustainable aviation fuel development and manufacturers' research into upcoming design ideas are the two key areas of action.

II. THE PILLARS OF AVIATION INDUSTRY'S CLIMATE ACTION STRATEGY

The quantity of fuel used per each flight has been cut in half since 1990 because of major improvements in the aviation sector's fuel and CO_2 efficiency. In other words, aircraft made today would emit half as much carbon emission relative to 1990. Infrastructure upgrades, technology developments, and operational improvements have all contributed to this.

However, as a result of an increase in air traffic volume, both in terms of cargo and passengers, aviation emissions as a whole have gone up. In order to achieve both of these objectives—reducing the global warming impact and attaining economic growth through connectivity—the industry's climate action framework has been created.

Diving into the Industry's climate action strategy pillars, we have

- Sustainable Aviation Fuel
- Operational Improvements
- Infrastructure
- Greener Airplane Materials

III. SUSTAINABLE AVIATION FUEL

The solution to efficient and environment friendly airline travel would be the development of an alternative aviation fuel, which would highly contribute to the emissions-reduction strategy of the industry. By using alternative aviation fuels compared to fossil fuels we can bring down CO_2 emissions by around 80%, without any significant changes made to the fuel supply systems. SAFs, or Sustainable Aviation Fuels, aim to produce jet fuels that generate fewer greenhouse gases during manufacture and combustion when compared to the industry's standard petroleum-based jet fuels. As a result, both the method of fuel production and the carbon source used have a significant impact on the degree of decrease. We have also brought to light some research that demonstrates that while some SAFs claim to considerably reduce emissions, others are produced on a large scale.

Commercial airlines are seen majorly using Jet A and Jet A-1 kerosene fuels. These fuels are a mixture of paraffins, olefins and naphthene They a hugely derived from petroleum. Companies like Airbus, are trying to find ways to use Hydrogen as fuel, as it produces water vapour when combusted. But developing Hydrogen burning engines are too far in the future. Therefore, the majority of companies are focusing on fuels that can be used with pre-existing jet engines. As a result, they must possess jet fuel-like characteristics, such as low-temperature performance and flow and the energy that is released when burned. One such way for fuel manufacturers to achieve these specifications is to blend SAFs with conventional jet fuel. Though the ratio required to blend it with Jet A-1 varies quite a bit, SAFs are often blended 50:50 with it. Additionally, there is interest in SAFs that are 100% pure and require no blending, none have been commercially approved and might take 3-5 years to get to that point, says Rick Barraza - Vice president of administration of Fulcrum BioEnergy.

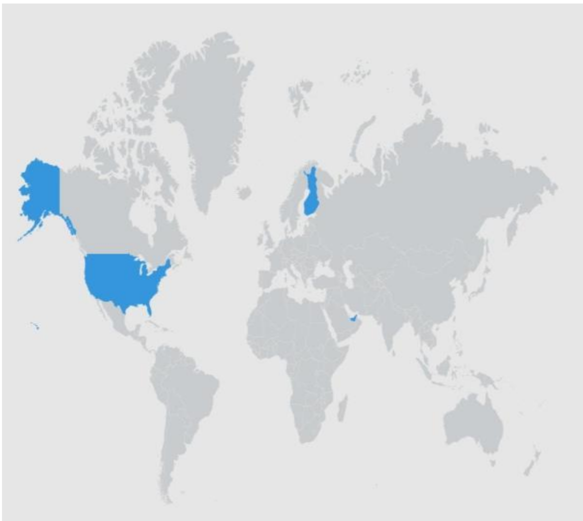

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Fig 1. Initiatives around the world.

Since 2008, when a commercial aeroplane using biofuel made its first test flight, the industry and its partners have worked extremely hard. Since 2011, a quarter of a million aircraft have flown on biofuel blends, thanks to certification from the international fuel standards organisation ASTM.

Using feedstocks that reduce the danger of unintended social and environmental repercussions, such as deforestation, we may now manufacture SAFs, or sustainable aviation fuels. Because the industry does not want to make the same mistakes made with 1st generation fuels, it is exclusively investigating 2nd generation biofuels, i.e., non-food biomass generated fuels.

These are some of the feedstocks which are currently used to produce Sustainable Aviation Fuels:

- Plants grown in saltwater
- Used oils and fats (ex: cooking oil and tallow)
- Waste gases from municipal solid waste
- Non-food crops that are cultivated on marginal land or in a rotation with food crops
- Algae
- Cellulosic waste

One significant advantage of biofuels is that they can easily be blended with the current supply of the fuel since they are "drop-in" fuels, i.e., they possess the same properties as the currently used jet fuels. In organisations like the Sustainable Aviation Fuel Users Group (SAFUG) and the Roundtable on Sustainable Biomaterials (RSB), which administers sustainability certification programmes, the aviation industry is seen working together. All in an effort to guarantee that any fuel utilised by the sector is, in fact, sustainable.

There are three main ways to make Sustainable Aviation Fuel: (All 3 can be used at a similar blend level of 50%).

- From Hydro processed Esters and Fatty acids (HEFA)
- Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)
- Alcohol-to-jet Synthetic Paraffinic Kerosene (ATJ-SPK).

We must remove the oxygen from the molecules in unused vegetable oils or waste fats, greases, and oils in order to produce HEFA fuels. The ICCT states that these combinations are then processed with hydrogen to produce hydrocarbons that are typically between 10 and 20 carbons long, the ideal length for jet fuels. When compared to Jet A and Jet A-1, these fuels are the most cost-effective SAF technology.

Scientists oxidise a wide range of plant and human wastes to create the Fischer-Tropsch- SPK, and the by-products are used to synthesis gas, a mixture of hydrogen and carbon monoxide. Typically, catalysts like iron, ruthenium, or cobalt are added to gas to start the Fischer-Tropsch synthesis, which creates the hydrocarbons.

Plant and agricultural wastes, as well as crops like corn and sugarcane, are the sources used to produce alcohol-to-jet-SPK. After converting these feedstocks, scientists typically obtain ethanol or isobutyl alcohol. Next, by eliminating water, they are upgraded to long-chain kerosene, and to create longer ones, we treat them with hydrogen and mix short-chain hydrocarbons.

Nevertheless, the environmental effects of these three alternative fuels are not comparable. The amount of greenhouse gases produced when producing these alternative fuels was recently revealed by a report from the ICCT, which included the collection of the carbon sources, synthesizing of these fuels, and their combustion in the engine. The information came from two United Nations initiatives: the International Civil Aviation Organization's Carbon Offsetting and the Reduction Scheme for International Aviation programme.

According to the ICCT, alcohol-to-jet-SPK fuels created higher emissions when compared to HEFA or Fischer-Tropsch-SPK fuels. This was because alcohols manufactured from starch- based crops required a lot of energy to produce and emit a lot of greenhouse gases.

Fischer-Tropsch-SPKs fuels are not being produced by most fuel companies, HEFA is the fuel currently in production by most companies as it has the lowest lifetime GHG emission, depending on the feedstocks.

But the hard reality is that airlines aren't using a lot of SAFs as of now relative to the total amounts of jet fuels being used actively. "It is less than 0.1%worldwide," says Pavlenko.

Fig 2. (below) SAFs Progress since 2008.

To take a look at specific cases, for better understanding, United had recently used 3.8 million L of SAFs annually as opposed to 15 billion L of normal jet fuel annually. United has agreements with World Energy and Fulcrum to

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increase the use of SAFs. Similarly with the Finnish company Neste, agreements to purchase SAFs by Delta and JetBlue have been made. These arrangements give airlines the source of certainty for future fuels and also provide a future market for the fuel companies. Since the first flight utilising sustainable aviation fuel launched in 2008, a lot of progress has been viewed.

Table 4.Below is a snapshot of the breakthrough of sustainable aviation fuel today and its advancement through the years.

Carrier	Date of first SAF flight	Details
Air New Zealand	December 2008	Technical test flight on a Boeing 747
Japan Airlines	January 2009	Technical test flight on a Boeing 747
Finnair	July 2011	Series of flights on an Airbus A320-family aircraft between Amsterdam and Helsinki
Interjet	July 2011	Commercial flight on an Airbus A320 between Mexico City and Tuxtla Gutierrez
AeroMexico	August 2011	Commercial flight on a Boeing 777 between Mexico City and Madrid
Iberia	October 2011	Commercial flight on an Airbus A320 between Madrid and Barcelona
Thomson Airways	October 2011	Commercial flight between Birmingham and Arrecife on a Boeing 757
Air France	October 2011	Series of flights on an Airbus A320-family aircraft between Toulouse and Paris
Air China	October 2011	Technical test flight on a Boeing 747
Alaska Airways	November 2011	Series of commercial flights on Bombardier Q400 and Boeing 737 aircraft
Thai Airways	December 2011	Commercial flight on a Boeing 777 between Bangkok and Chiang Mai
KLM	May 2014	Commercial flight from Amsterdam to Aruba on Airbus A330-200
GOL Lineas Aéreas	June 2014	Series of flights during the FIFA World Cup
Nextjet	June 2014	Commercial flight from Karlstad to Stockholm
Finnair	September 2014	Commercial flight from Helsinki to New York on Airbus A330
Lufthansa	September 2014	Scheduled flight from Frankfurt to Berlin
Scandinavian Airlines	November 2014	Flights between Stockholm and Ostersund and Trondheim and Oslo on Boeing 737 aircraft
Norwegian Airlines	November 2014	Flight between Bergen and Oslo on a Boeing 737
Hainan Airlines	March 2015	Commercial flight between Shanghai and Beijing on a Boeing 737
Alaska Airlines	June 2016	Two commercial flights from Seattle to San Francisco and Washington D.C.
Hainan Airlines	November 2017	Commercial flight from Beijing to Chicago on Boeing 787
China Airlines	December 2017	Delivery flight of A350-900 from Toulouse to Taipei
Qantas	January 2018	Commercial flight from Los Angeles to Melbourne on Boeing 787-9
Air Canada	May 2018	Commercial flight from Edmonton to San Francisco on A320-200
SpiceJet Airlines	August 2018	Demonstration flight on Bombardier Q400 from Dehradun to Delhi
jetBlue Airways	September 2018	Delivery flight of A321 from Mobile, Alabama to New York
Etihad Airways	January 2019	Commercial flight from Abu Dhabi to Amsterdam on Boeing 787
China Southern Airlines	February 2019	Delivery flight of A320NEO from Toulouse to Guangzhou
Braathens Regional Airlines	May 2019	'Perfect Flight' from Halmstad to Stockholm on ATR 72-600
Various	May 2019	21 private aircraft flew to Geneva to the annual European Business Aviation Convention & Exhibition (EBACE)
United Airlines	June 2019	Eco-friendly commercial "Flight For the Planet" from Chicago to Los Angeles
Delta	July 2019	Delivery flight of A321 from Mobile, Alabama to Kansas City (first in series of 20 delivery flights to Delta powered by sustainable fuels)
Egyptair	July 2019	Delivery flight of Boeing 787 from Seattle to Cairo
Finnair	August 2019	First two flights backed by "Push for change" initiative from San Francisco to Helsinki

Table 5. The table below shows the 7 internationally approved processes through which sustainable aviation fuel can currently be made.

Pathways and processes	Feedstock options	Producers using the pathway	Date of approval	Current blending limit
Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)	biomass (forestry residues, grasses, municipal solid waste)		2009	up to 50%
Hydroprocessed Esters and Fatty Acids (HEFA-SPK)	algae, jatropha, camelina	Alt Air	2011	up to 50%
Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (HFS-SIP)	microbial conversion of sugars to hydrocarbon	Amyris	2014	up to 10%
FT-SPK with aromatics (FT-SPK/A)	renewable biomass such as municipal solid waste, agricultural wastes and forestry residues, wood and energy crops		2015	up to 50%
Alcohol-to-Jet Synthetic Paraffinic Kerosene (ATJ-SPK) (isobutanol)	agricultural waste products (stover, grasses, forestry slash, crop straws)	Gevo	2016	up to 30%
Alcohol-to-Jet Synthetic Paraffinic Kerosene (ATJ-SPK) (ethanol)	agricultural waste products (stover, grasses, forestry slash, crop straws)	LanzaTech	2018	up to 50%
Catalytic hydrothermolysis synthetic jet fuel (CHJ)	Triglyceride-based feedstocks (plant oils, waste oils, algal oils, soybean oil, jatropha oil, camelina oil, carinata oil and tung oil)	ARA and Euglena	2020	up to 50%
High Hydrogen Content Synthetic Paraffinic Kerosene (HHC-SPK)	biologically derived hydrocarbons such as algae	IHI World	2020	up to 10%

IV. OPERATIONAL IMPROVEMENTS

Efficiency gains and operational enhancements can make a significant difference.

There are chances to reduce fuel consumption and the pollutants produced by the aircrafts at every stage of operation. These tasks can range from creating and putting into practise new arrivals procedures to something as simple as making sure the plane's engines are clean.

1. On the ground:

When a flight is parked at airport gates, there is a small unit existing at the tail of the aircraft that functions as a generator, referred to as the auxiliary power unit (APU) which kicks on. Power is required by aircraft to start the engines, produce electricity, and provide air conditioning. However, an increasing number of airports are working to outfit their gates with fixed electrical ground power and pre-conditioned air. As a result, the APU can be turned off by the pilots, conserving fuel and reducing aircraft noise over the ground.

2. Departure:

For transportation from the gate to the runway we use aircraft taxi, there are some techniques which are in operation, like the single-engine taxiing, some devices such as self- driving devices are still under development, these improvements enable the aircraft to land without using all of its engine power. Another such method is known as "green departures," which is used to help the aircraft take off and climb steadily so that it can get to the most crucial part of flight, the cruise, faster.

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3. Cruise:
Aircraft‘s burn lesser fuel with lesser weight on board, despite their size. Hence if we can reduce weight of items that are carried from food service trolleys, to supplying each flight with exactly the correct amount of water, then we can make a significant reduction in fuel consumption and savings.

Air traffic controllers, as well as Airlines are working side by side to use the weather at elevated heights to the advantage. Studying of wind patterns much prior to departure is done by the pilots and the flight planners. Then the aircraft is routed along the strong wind streams. The use of these wind streams has decreased both emissions and flight time, despite flying for longer distances.

4. Arrival:
Aircraft typically drop from cruise to landing in a step-by-step process, going from one altitude to the next before "levelling out" by turning on the motors or engines. With new technology, surveillance which is much more accurate, allowing the location of each aircraft is a more comprehensive view of the air traffic environment. Continuous descent operations, a methodology that enables the flight to nearly "glide" into the airport with a very low setting engine, has resulted from this. This reduces the amount of fuel used while also lessening the noise's influence on the neighbourhood. We have started deploying this widely all over the world, depending on the weather and air traffic.

V. INFRASTRUCTURE

The airline industries are focusing to lessen congestion and delay and the one way to achieve that is by collaborative decision-making (A-CDM) which ensures that the flight engines don‘t start without confirmed time for take-off and ensuring a slot at the destination airport.
Air traffic management

The biggest impact on aircraft fuel efficiency made through infrastructure area is the air traffic management system. The amount of fuel a plane burns depend on what route the aircraft takes, from the height it flies to the weather condition that it flies through and thereby the amount of CO2 it emits. The air navigation service providers (ANSPs) who take care of the air traffic control service, manage all these factors.

ANSPs are helping the aviation industry, by optimising aircraft performance and also making better use of airspace design, this helps enhance the environmental performance worldwide. ANSPs aim to optimise flight and ground operations, improving the overall performance as they work with regulators, aircraft manufacturers, airports, pilots and engineers to achieve the same.

New technologies like satellite-based navigation and procedures such as _performance- based navigation‘ are being introduced, with these flights can now follow optimised, highly direct routes which have more accuracy and efficiency. Lowering the unnecessary travel time reduces the fuel and hence CO2 emissions and enables the plane to utilize this extra airspace by accommodating increasing air traffic and reducing congestion and delays.

VI. GREENER AIRPLANE MATERIALS

Researchers and businesses are looking at new composites materials and coatings techniques that can make the aircraft lighter, thinner, and more environmentally friendly than the materials used today, in an effort to help airlines go green.

A plane's environmental effect is greatly influenced by the materials used in every component of the aircraft, which also impacts the weight, aerodynamics, and resistance to damage from pressure changes or air turbulence of the aircraft. As lighter planes require less fuel to run, which results in reduced emissions, an airplane's weight has a substantial impact on its carbon footprint. Hence, altering the materials used to construct aircrafts is one way to make them lighter.

In the past, metal, typically an alloy of aluminium, was used to make aeroplanes. According to Samit Roy, an aerospace engineer at the University of Alabama, certain modern aircraft, like the Boeing 787 and Airbus A350, now contain roughly 55% composite components.

For instance, some companies employ polymers with embedded carbon or glass fibres to construct the wings, tails, and portions of the fuselage of aircraft. Composites have the potential to cut an aircraft's weight by up to 20%. New composites made of carbon fibre and nanoparticles are being developed. These materials can also be 3D printed and are very lightweight. Due to the ability to make parts in the precise size and shape required rather than having to cut them out of a larger piece of material as is the case with aluminium, this results in a significant reduction in material waste.

We are also diving into the possibility to make these composites conductive. "A lightning that strikes an flight made of aluminium, such as the 747, just pierces its skin with little to no damage," says Roy.

However, because the majority of composite materials used in aircraft are not naturally conductive, a direct zap might cause significant harm. Aircraft makers like Boeing and Airbus cover the composite flights' fuselages with copper mesh as a defence against this, although doing so increases weight and cost of the aircraft. Researchers are creating reinforced composites with carbon nanotubes or nanographene, as well as conductive polymers, to increase

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electrical conductivity and enable aircraft to handle the thick copper covering.

The basic goal of coatings is to give surfaces new capabilities and attributes. Coatings can protect against corrosion, add insulation, lessen air friction, or even just add a brand logo on the plane. Almost every component of a commercial aircraft receives some sort of coating, be it on the glass to provide additional protection from UV light, the flight surfaces to make them stain-resistant, and the landing gear to keep the machinery from rusting.

Preventing a part from rusting and malfunctioning is one of many main functions of coatings. Hexavalent chromium, usually known as chrome, was the standard corrosion inhibitor for the aircraft industry for many years. Unfortunately, this substance is toxic to the eyes, skin, and respiratory system and is a recognised carcinogen. For a very long time, coatings businesses have been attempting to get rid of the substance. Now, chrome-free and alkali earth materials are considered as substitutes, as they may also be lighter in addition to being less hazardous.

Therefore, if we develop a primer that is 20–30% lighter than current conventional chromated primers, it will directly affect the aircraft's fuel economy, says the global marketing manager for aircraft coatings at PPG Industries – Robin Peffer.

Another option to increase sustainability is to alter the way coatings are applied. Chrome-based coatings frequently require spraying. However, a lot of the substitute anticorrosion coatings can frequently be applied by immersing the component parts in a coating solution. Coating companies can apply the substances more effectively, especially to intricate shapes, thanks to this procedure. Since we can apply the coating to the surfaces more uniformly than we can with spray, Peffer claims that we can achieve weight savings of up to 75% or more.

Another potential method for applying coatings is plasma electrolytic oxidation. This process is comparable to anodizing, which strengthens and inhibits corrosion by electrochemically converts the metal to its oxide. Since, Plasma electrolytic oxidation coatings are three to four times more wear-resistant and need to be replaced less frequently. A longer-lasting coating therefore reduces the amount of time spent in the repair hangar and the amount of material used, lowering expenses for the airline and enhancing sustainability.

VII. CASE STUDY

The proposed project pivots on the importance of sustainability in aviation and the measures taken by several countries in implementing the same. The case study of our project is a comprehensive analysis on the aircrafts that are designed by several countries including India with the primary focus on reducing emissions. Reducing emissions of aircrafts has an important contribution in achieving greener aviation. The two main subjects of our study are Aircrafts using SAF (Sustainable Aviation Fuel) and the Aircrafts designed with light weight using special materials and techniques referred to as Greener Airplane materials and the existing aircrafts presented support our solutions as implemented evidence.

VIII. SUSTAINABLE AVIATION FUEL

The use of sustainable aviation fuel in aircrafts has provided a beneficial result of reducing carbon emissions by 80%. This is used in two ways such as blended with jet fuel and 100% of SAF. The two aircrafts that we examine for the case of SAF are Airbus 380 and Airbus320neoLR.

1. AIRBUS 380:

The Airbus 380 is one of the topmost aircrafts in achieving sustainable air growth as its designed for the main objective of reducing carbon emission per seat. Three aircrafts were designed by Airbus that are powered with SAF. Airbus 380 is the third aircraft of Airbus designed and powered unblended and 100% SAF. This aircraft sustained for three hours in flight and this implies the achievement of SAF. The first aircraft A350 and the second

Aircraft 319neo powered by SAF paved way for the Airbus 380. The SAF provider for A380 is ―Total Energies‖. The method used to prepare this fuel is HEFA which furnishes the fuel free from sulphur and also aromatics, and it comprises used cooking oil and waste fats. This aircraft started its flight in 2007 and it is said to be the world's largest and compact aircraft. It has four engines and one of its Rolls-Royce Trent 900 engines operated with 100% SAF. The main focus of Airbus is to achieve net zero carbon emissions by 2050 and this aircraft gives a key path that SAF can reduce emissions up to 71% in future. The A380 is noted as the ‗Zero e Demonstrator‘which marks the milestones of introducing zero carbon emissions in future.

Two flight tests using the A380 superjumbos composed of 100% biofuel, made of used cooking oil and fats, were conducted. Code-named MSN 1, the A380's initial flight test took out from Toulouse, France's Blagnac Airport and travelled for three hours before touching down. A second test flight was made using the same A380 to evaluate how the SAF performed during take-off and landing. The trip was made by plane from Toulouse to Nice, and it took about 2.5 hours. About 27 tonnes of fuel was produced in Normandy, France, were sent to Airbus by the French oil and gas business Total Energies. SAF has a better chance of providing between 53 and 71 percent of the necessary carbon reductions, according to ATAG's 2050 research report. The aircraft satisfied all the important requirements of sustainability with some steps left with engine manoeuvres.

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Table 6. Specifications of Airbus 380.

DIMENSIONS	
Aircraft Length	73 meters
Cabin length	50.68 meters
Aircraft Height	24.1 meters
Wing area	843 square meters
Wing span	79.8 meters
Fuselage diameter	7.14 meters
Wheel base	30.4 meters
Track	14.3 meters
WEIGHTS	
Maximum Fuel Capacity	320,000 liters
Maximum Zero fuel weight	361,000 kg
Maximum ramp weight	562,000 kg
Typical Volume Payload	664,000 kg
ENGINE SPECIFICATIONS	
Powerplants	Rolls-Royce Trent 900 providing 363kN thrust Four 311kN thrust producing engines but initially gave 302kN and furtherprovided 374kN thrust
PERFORMANCE	
Range with maximum number of passengers	15,000 km
Maximum operating speed	0.89 Mach
Long range cruising speed	0.85 Mach
Service ceiling	43.000 ft

Fig 3. 27 April 2005, the first flight test of A380.

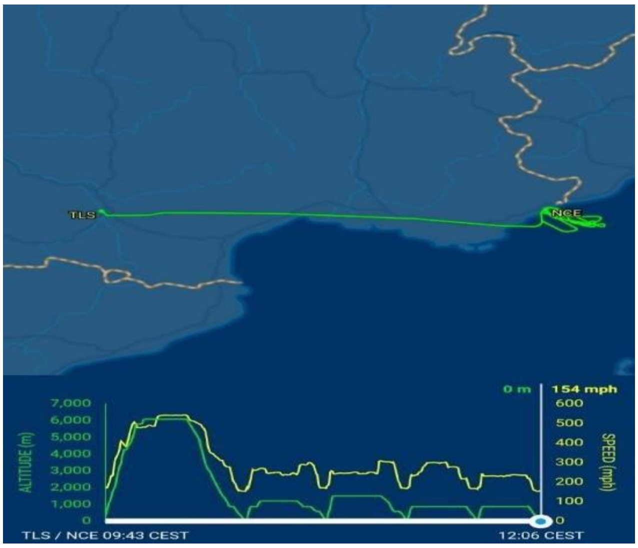

Fig 4. SAF performance tracked during second flight test.

2. AIRBUS A321neoLR

The Airbus A321neoLR is the longest fuselage member which has the longest range compared to any single-aisle jetliner. The Transatlantic Narrowbody flights are now operated by A321, working as an environmental operator. This aircraft started its flight in 2018, being a steady narrowbody aircraft. The A321LR marks the 19% saving per seat per kilometer in carbon dioxide emissions compared to Boeing 757-200 aircraft. This is a carbon neutral flight indicating the use of the blended SAF. Which was powered by blending 10% SAF with kerosene. The carbon emissions could be reduced by 28%, if the blend of SAF is 35%.

The plane features two different kinds of engines: a CFM LEAP-1A and a Pratt & Whitney Pure Power PW1100G-JM. The second LEAP engine provided the vehicle's power and this secured a certification of flying more than 400 hours in 160 flights. It also covered a distance of 4750 nautical miles in 11 hours of flight which is a record-breaking flight range from Seychelles islands to Toulouse, France. A321neo completed 15 test flights by providing a good flight behaviour, fuel consumption and also passenger comfort. The test analysis concluded that the aircraft met all of the Airworthiness Criteria.

The SAF used is made up of sustainable feedstocks like cooking oil and it is prepared by the process of HEFA. This SAF was tested and certified by International Sustainability and Carbon Certification system (ICCS) for usage and it met all the sustainable requirements of the European Union‘s Renewable Energy Directive. NEO offers minimal alteration with greatest benefit by considering two cutting-edge engine options; the PurePower PW1100G-JM geared turbofan from Pratt & Whitney and the LEAP-1A from CFM International, as well as the SharkletTM fuel-saving wingtip devices from Airbus. They increase fuel efficiency per passenger by 20% while also extending the range by up to 500 nm or

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adding two tonnes of payload. The long-range A321LR version of the A320neo offers increased range and can carry 206 passengers on flights of up to 4,000 nautical miles by storing extra fuel in three Additional Centre Tanks (ACTs). With a 30 percent reduced fuel burn per seat and a 50 percent lower noise, the Sharklets on the wings improve aerodynamics, and the aircraft's fuel-efficient engines guarantee an improved environmental performance.

Table 7. Specifications Of Airbus A380.

DIMENSIONS	
Overall length	44.51 meters
Cabin length	34.44 meters
Fuselage width	3.95 meters
Height	11.76 meters
Wing span	35.80 meters
Wheel base	16.90 meters
Track	7.59 meters
PERFORMANCE	
Range	7,400 km
Maximum payload	56,200 lb
Maximum Thrust	145 kN
Engine	Pratt & Whitney PW1133G-JM geared turbofans

Fig 5. SAS receives the first Airbus A321LR using sustainable aviation fuel (first look).

IX. GREENER AIRPLANE MATERIALS

The study of using greener airplane materials indicated the use of alternate materials for engines, special coating techniques, and composite materials on the several parts of aircrafts. The main objective of using the greener airplane materials is to reduce the weight of aircraft, increasing the sustainability thereby reducing emission. This case study allows the future aircrafts to use lighter materials like carbon fibre and have other fuel conserving innovations that can save up to 40% fuel.

1. BOEING 787 Dream Liner:

The Boeing 787 had its first flight on December 15th, 2009 which initiated a nine- month long flight test programme. The 787 family consumes 20 to 30 percent less fuel, emits 20 to 30 percent less carbon dioxide, and its noise footprint is 60% less than that of comparable aircraft. This speed and fuel efficiency is achieved by the aircraft's wing shape and structure. The 787 is also the first widebody commercial airplane with a carbon composite material fuselage constructed by a substantial one-piece barrel section. The plane is significantly lighter, more aerodynamically effective, and consequently more fuel- efficient owing to this cutting-edge method, which resulted in a decrease of 40,000–50,000 fasteners per piece and 1,500 aluminium sheets. Newer, more fuel-efficient jet engine versions made by Rolls-Royce and General Electric power the 787.

This 787 Dreamliner's fuel efficiency is capable of producing outstanding environmental results. For an equivalent mission, the aircraft will consume 20% less fuel than a similar-sized aircraft that is currently in use. Compared to earlier aircraft models, the Boeing Dreamliner delivers a double-digit percentage point reduction in fuel consumption. It is fuelled by effective engines, lightweight composite materials, and modern onboard systems. The aircraft was named as the ―Greenliner‖ in an Airshow conducted in Dubai, 2021. In comparison to the same flight in 2019, the outcome was a completely sustainable flight that reduced carbon dioxide emissions by 72%.

The 787 Dreamliner uses 20 percent less fuel than a similarly sized aircraft already in operation because of the four essential technologies. The carbon fibre composite materials are the essential materials used in 787 Dreamliner. The performance of the 787 is influenced by new engines, higher use of lightweight composite materials, more effective system applications, and contemporary aerodynamics.

By volume, the Boeing 787 plane has 80% composite material. The material composition is composed of 50% composite, 20% aluminium, 15% titanium, 10% steel, and 5% other materials. The leading margins of the wings and tail are made of aluminium. Although titanium is primarily used in engines and fasteners, Steel is employed in a variety of places. About 32,000 kg of CFRP composites, constructed with 23 tonnes of carbon fiber, are found in fuselage, wings, tail, doors, and interior, all featuring composite materials are found in the Boeing 787 aircraft. To offer optimal strength in the widest range of load routes, reinforcing fibers are arranged in particular ways. The Boeing 787 Dreamliner's onboard starting power supply is made possible by a Li-ion battery which was implemented for the first time. Blended Winglets, a cutting-edge invention that can reduce fuel burn by as much as 4%.

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Table 8. Specifications of Boeing 787 Dreamliner

DIMENSIONS	
Fuselage length	56.7 meters
Fuselage Height	5.94 meters
Fuselage width	5.77 meters
Wing area	377 square meters
Wing span	60.1 meters
Wing sweep back	32.2 meters
Aircraft Height	16.9 meters
WEIGHTS	
Maximum Fuel Capacity	126,206 liters
Maximum Zero fuel weight	161,000 kg
Maximum take-off weight	227,930 kg
Maximum landing weight	172,000 kg
Operating Empty weight	119,950 kg
PERFORMANCE	
Range	13,620 km
Maximum operating speed	0.90 Mach
Thrust	64,000 lbf
Engines x two	General Electric GEnx-1B Rolls-Royce Trent 1000
Cargo Capacity	136.7 cubic meters
Take off distance at MTOW at sea level (ISA)	2,600 meters

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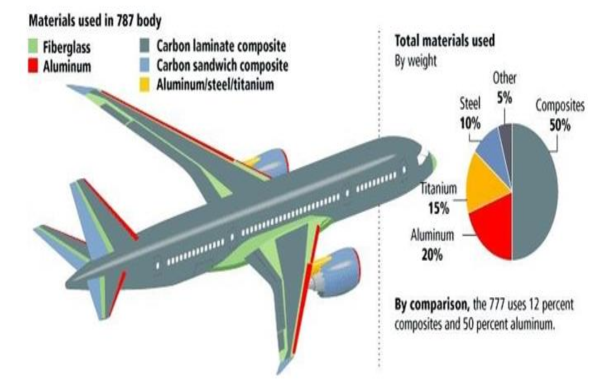

Fig 6. Composition of various materials used in Boeing 787 Dreamliner.

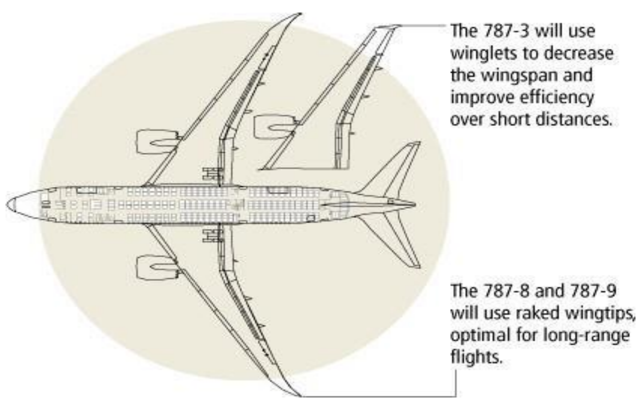

Fig 7. Wing Aerodynamics of Boeing 787 Dreamliner comparison.

2. LCA-TEJAS:

The lightweight Indian aircraft Tejas is composed of 45% composites by weight, of which around 25 percent was created at CSIR-NAL. The Tejas is a single-seat, single-motor, light supersonic fighter aircraft developed by Hindustan Aeronautics Limited. The aircraft consists of titanium alloys, carbon fiber composites, and aluminium-lithium alloys. 95 percent of the airframe's surface area are made up of composite materials. A single piece of carbon fiber reinforced polymer is used to create both the upper and lower wing skins. An eco-assessment of the additive manufacturing of LCA-Tejas materials showed a 40% reduction in carbon emissions. The airplane was built using lightweight materials such as carbon composites, lithium and titanium alloys, and aluminium.

The structure has a shoulder mounted delta wing, has a fine but lacks a horizontal tail. The wing structure consists of carbon fiber-reinforced plastic ribs and composite spare parts.

Table 9. Specifications OF LCA-TEJAS

DIMENSIONS	
Fuselage diameter	1 meter
External length	13.2 meters
External Height	2.6 meters
Wing area	38.4 square meters
Wing span	8.2 meters
Tail Height	4.4 meters
WEIGHTS	
Empty weight	6,560 kg
Gross weight	9,800 kg
Maximum Take-off weight	13,500 kg
PERFORMANCE	
Range	3,000 km
Maximum payload	5,300 kg
Maximum Thrust	12,100 lbf
Engine	General Electric F404-GE-IN20
Fuel Capacity	320 US gal
Maximum cruising speed	1,066 knots

The front starboard side of the Tejas LCA is equipped with wing and fuselage tanks as well as in-flight refuelling probes. On the inner and mid-board wing and fuselage centreline hard-points, drop tanks with a capacity of up to 4,000L may be carried. The prototype development aircraft is equipped with General Electric F404-GE-F2J3 turbofan engines with afterburners. Three engines make up the LCA-Tejas, one in the middle of the fuselage and two underneath the port side air intake. For carrying stores, it includes eight external hardpoints. It can fly at a peak speed of 2,205 km/h and a height of 15,200 m. The aircraft has a range of 3,000 kilometres and a service ceiling of 16,500

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metres. The maximum take- off weight for the aircraft is 13,500 kg, and it weighs about 5,450 kg.

Fig 8. Light Combat Aircraft Tejas (HAL, India).

X. FAILED THEORIES

For finding a solution to the problem, knowledge in its failed theories of the specific problem is very important. Now we will be looking into some of the drawbacks of the using greener materials like composites & Sustainable Aviation Fuels - SAFs alongside specific aircraft's that have implemented the same.

1. Drawbacks of using composite materials:

- It can be challenging to determine whether the inside structure of the aircraft has been harmed because materials do not break that easily. This makes inspection more difficult and expensive. Composite materials' higher initial cost in comparison to metals may be their biggest drawback for makers of aircraft and parts. The costlier end product is mostly caused by the price of the fibre and the intricate manufacturing process.
- Materials have had a short shelf life and needed to be transported and stored in a refrigerated environment. Because the glue used in composite material fails at temperatures as low as 150 degrees, these aircraft must take additional precautions to prevent fires. Composite material fires pose a health risk to people by releasing dangerous chemicals and microscopic airborne particles. Structures are susceptible to failure at temperatures above 300 degrees Fahrenheit. Galvanic corrosion of nearby aluminium components must be avoided through isolation. Composites must be completely cleansed of all pollution prior to being repaired.
- Delamination of the composite material was one problem that came up during the inspection procedure. The most frequent reason for delamination is impact on composite parts. This is because water may seep through a layered structure, and as the water freezes and thaws, the issue gets worse.
- Unlike aluminium, common aviation composite materials are not conductive; therefore they cannot shield the fuel tank from direct lightning hits.

2. Aircrafts that implemented Composite materials:

- In the 1950s, Boeing utilised fibreglass for the first time in an aircraft. Boeing boasted that its new 787 Dreamliner was made up of 50% composite materials when it debuted it in 2012.
- The Airbus A350 also uses more than 50% composite materials (by weight), the most ever used on a commercial aircraft, primarily carbon fibre reinforced plastic (CFRP), including the majority of the plane's wings. CFRP has a higher strength-to-weight ratio than metal.

3. Drawbacks of Using SAFS:

- The cost of manufacturing SAF is greater than that of regular jet fuel. In the light of that SAF is newer and produced in smaller quantities than conventional jet fuel, economies of scale simply do not exist to reduce the price to that of jet fuel. Consumers will most likely be responsible for covering the extra cost of sustainable aviation fuel. May only be effective for certain types of flights.
- The final fuel product still contains conventional jet fuel. This cost will be borne by the consumer. Given the cost of fuelling a private jet, this is not surprising. The result is not only that it is more expensive, but it also has an impact on the effectiveness of SAF.
- Another disadvantage of SAF is its scarcity. SAF, of course, cannot be stored in the same tanks as jet fuel. As a result, airports require alternate facilities to support this alternative. Naturally, this necessitates additional airport investment. The issue here is what the airport gains from supplying SAF.
- There are now 38 airports offering sustainable aviation fuel, according to the ICAO. There may be obstacles to growth since the use of sustainable aviation fuel is not yet at the same level as that of conventional jet fuel. Only HEFA can be an alternative fuel in commercial use due to its development and simplicity in comparison to other approaches. Depending on the size of the plant and the stage of deployment, the cost of producing one ton of HVO might range from €1100 to €1350. When upgrading to HEFA, the isomerisation procedure has a negligible additional cost. Lack of feedstock is this route's biggest drawback.
- On a worldwide basis, UCO and tallow are relatively rare commodities, and the supply of virgin vegetable oil is constrained due to issues with sustainability and land availability. The potential and sustainability of novel crops including camelina, carinata, and oil-bearing alagae are being studied. Another potential

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feedstock for HEFA plants is sugar-to-lipid fermentation.

4. Aircrafts that have used SAFs:

The Boeing 737 MAX7 jet was the first commercial flight with passengers to use a 100 percent drop in sustainable available fuel for one of the plane‘s two engines. The Airbus completed the first A380 flight using only Sustainable Aviation Fuel (SAF). And Indigo tested its brand new A320 Neo with a blend of 10% SAF and 90% regular fuel.

XI. RESULTS

In this paper we have identified a step-by-step process to control CO2 emissions through Operational improvements and infrastructural advancements, throughout all phases of the flight – during departure, and arrival and in the most important phase – Cruise. We have also explored the advantages of Sustainable Aviation Fuel compared to the petroleum-based jet fuels used today, alongside which we differentiated the various processes to make SAFs and recognised the most effective method to be the HEFA.

This study also brings into light the challenging accepts of introducing greener airplane materials and different coating techniques that can be used to make aircrafts lighter, highly aerodynamic and more resistance to wear and tear. We discussed 4 different case studies of Aircrafts, focusing on their exact percentage of CO2 emission reduction and performance characteristics and disclosed various failure theories and drawbacks as a base for future research.

XII. FUTURE WORK

This study can be extended by employing various other methods for the production of Sustainable aviation fuel or other fuel like Hydrogen based fuel to reduce the amount of carbon emissions. Furthermore, the challenges of re-introducing supersonic aircrafts can be explored. Advancements in the field of greener materials using different composites and other coating techniques can be implemented.

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