How can we make the aviation industry more sustainable?

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Love to learn academic scholars' project.

Abbreviations and Definitions:

SAF: Sustainable Aviation Fuel

Jet Fuel: Referring to Jet A, Jet A1 and Jet B Kerosene hydrocarbon-based fossil fuels which are combusted in normal turbofan jet engines.

IATA: International Travel Association

IEA: International Energy Agency

Feedstock: A raw material used to supply or fuel an industrial process (including manufacturing of SAFs).

CHG: Greenhouse Gas Emissions

FMS: Flight Management System

RNP: Required Navigation Performance

Airbus: Dutch Multi-national aerospace company (specialises on commercial and military aircraft).

Boeing: American multi-national aerospace corporation (also designs rockets, satellites and missiles).

Cited Sources:

Shell, Airbus, Boeing, IATA, BP, London Heathrow, UK Government, GE (General Electric), Pratt and Witney, Rolls Royce, Simple Flying News, British Airways, United Airlines, Delta Airlines, Zero Avia, Wikipedia, CNN, National Geographic, PWC, TED-ED, UN (United Nations), University of Groningen.

Introduction:

Aviation has changed our world forever; for the better, and the worse. It is at the heart of connections between countries, allowed us to travel to far away, beautiful locations and provides countless opportunities for jobs and trade – providing vast amounts of money to world economies. However, we have failed to prevent or alter the significant impacts of the tremendously harmful emissions which are released by airplanes, and although planes have become more fuel efficient over time, much more needs to be done. Airplanes which burn fossil fuels account for approximately 2.5% of estimated global greenhouse gas emissions (according to the IDA) and are a significant contributor to the dangerous global warming of our planet. Adding up, global aviation industry emits around 1 billion tonnes of Carbon Dioxide (CO_2) into the atmosphere, from the 39 million flights each year (pre-pandemic according to IATA). Most airplanes run on one of 2 main Kerosene-based fuels – Jet A and Jet A1, which have slightly different properties and freezing points (therefore different carriers use them due to geographical location). Kerosene is used for airplanes because it contains lots of chemical energy (43 MJ/kg) when combusted, which propels the plane through the sky with lots of power, allowing them to fly to high altitudes, while carrying lots of passengers. However, this fuel releases Carbon Dioxide (CO_2), particulate matter (soot) as well as Sulphur and Nitrogen Oxides (NO_x) into the atmosphere, which are all primary greenhouse gases playing a considerable part in heating up the planet. Furthermore, particulate matter, such as tiny solid particles of soot can have adverse effects on air quality, and in addition to acting as greenhouse gasses, Sulphur and Nitrogen Oxides can lead to acid rain. To put the amount of a fuel that an airplane uses in perspective, a large Boeing 747-400 jumbo jet goes through 4 litres of kerosene per second – just imagine the quantities of greenhouse gases and other dangerous substances are released through the entire flight! Throughout this project I mention the different changes from an airline's point of view because the airlines, manufacturers and the governments controlling them will decide whether aviation will become more sustainable, or it will continue with its downward spiral of extreme Carbon emissions. The majority of commercial airlines do not particularly care about their Carbon emissions and will keep flying and releasing these dangerous emissions for more profit. However, airlines do care about their passengers, and if they believe that they may lose a significant amount passengers and popularity (in the not-so-distant future) because they are not sustainable but are damaging the environment significantly, they would certainly be willing to research and invest into new more sustainable technologies. Furthermore, with pressure from several governments around the world planning to ban short-haul flights less than 30 minutes, airlines are competing to reduce their Carbon footprint and advertise their projects on reducing their CO_2 emissions, ultimately to have a viable excuse for their short-haul flights. In this essay I will suggest 3 different modern and adventurous ways that the aviation industry may become more environmentally sustainable.

Using Sustainable Aviation Fuels:

Brief YouTube video on Sustainable Aviation Fuels, created by me:

https://tinyurl.com/SAF-video

The production of SAFs:

SAF is a safe alternative option to traditional jet fuel, which gaining traction in the aviation industry. SAF can be produced in huge amounts as it can be made from many different feedstock sources, including waste and cooking oils, fats / greases (FOGs are the leading source), non-recyclable plastic, and general food scraps that would otherwise go to landfill. SAFs are made from Hydrocarbon molecules through a process called Hydrodeoxygenation, which is when Oxygen originating from renewable raw materials is removed from it using additional Hydrogen. After this step is completed, impurities in the mixture, like Sulphur and Nitrogen are removed in this process, to make the resulting SAF fuel cleaner.

Why SAFs are sustainable:

It is sustainable from a lifecycle perspective as the SAF recycles all the CO_2 which the biomass has absorbed over its life (for example in the chemical reaction of Photosynthesis) and simply returns it to the atmosphere. It is the same as the normal Carbon cycle for a plant, when all the Carbon stores in their bodies is released into the atmosphere again when it dies and is broken down by respiring decomposers. Therefore, SAFs are completely sustainable for airplanes to use and emit into the atmosphere as from a lifestyle perspective there is no net addition of CO_2 to the atmosphere. However, fossil fuel-based Kerosene release CO_2 from the past, resulting in a net increase of the gas in the atmosphere. As a result, Sustainable Aviation Fuels reduces lifestyle Carbon emissions by up to 80% compared to the convectional fuel it replaced (IATA estimate), however this figure can vary depending on the source of the feedstock.

The usage of SAFs in aircraft engines:

Numerous tests have been conducted with SAFs on airplanes and all were successful, and the engines produced the same thrust and operated as usual as when using normal Jet Fuel. Therefore, many plane manufacturers (including Airbus and Boeing) certified their planes to allow airlines to fly with SAF onboard, with up to a maximum blend of 50% SAF and 50% regular Jet Fuel (for the meantime due to international standards restrict commercial flights to this 50/50 blend as research continues). This is a milestone achievement as it allows stability, safety, and reassurance for airlines as they can implement the fuel into existing infrastructure without massive prices or safety concerns.

Airline implementation of SAFs:

Many airlines, for example, US carrier United Airlines are using SAFs to power flights, on a continuous basis. This US airline made many pivotal achievements, including being the first airline to operate with 100% SAF, for an entire flight, on a single engine, while also embracing the goal of becoming 100% green by 2050. Consequently, many companies and airlines have invested into sustainable aviation fuels, leading to over 450,000 commercial flights partially powered by SAFs to date, but this only accounts for less than 0.01% of flights.

Airbus's commitment to SAF usage in modern aircrafts:

Although this is only a small proportion of yearly flights, this number is predicted to rise significantly after Airbus successfully carried out the World's 100% Sustainable Aviation Fuel (SAF) flight using an in-service military Airbus A330MRT (a mid-sized dual engine plane, specifically optimised for RAF operations). Therefore, manufacturers such as Airbus are aspiring for the 50/50 certification to be removed and flights could now undergo carrying 100% SAF. It is widely assumed that flying with 100% SAFs will be allowed by the year 2030. Hence, this shall inspire more airlines to switch to SAFs, as the cost of combining it with regular jet fuel is eliminated, hence helping them to reach the required aviation net-zero target by 2050, set by numerous international aviation associations.

Challenges associated with SAFs:

The estimated amount of SAF needed to fulfil aviation's net zero target will require an annual production capacity of 449 billion litres. However, producing SAF is, at present, significantly more expensive than extracting and producing jet fuel, due to the additional steps required and the current low demand from airlines. For example, multiple steps of heating and cooling; to separate the Water from the oil and mix the blend of both SAF and Jet fuel together. This requires lots of energy, making it presently the far more expensive option, and meaning that SAFs are not completely Carbon-Neutral. However, with more investment from airlines and worldwide governments, newer technology and infrastructure could be incorporated in the process, making the SAFs cheaper and even more accessible for airlines. In conclusion, I think that it is evident that SAF is the most accessible and easiest way currently to make aviation more sustainable, as it can fit and work with existing aircraft infrastructure which is primarily why its popularity among major airlines has surged recently.

Using Liquid Hydrogen-powered plane engines:

Benefits associated with introducing Hydrogen-powered combustion engines:

Hydrogen seems like a viable form of fuel to replace aeroplanes with, however there are many problems associated with its efficiency. Hydrogen has a specific energy of 120MJ/kg (amount of energy released when 1KG of the pure element is combusted), which is nearly 3 times higher than the energy of traditional Jet fuel (43 MJ/Kg). Therefore, at first glance it looks like it could easily replace jet fuel as it could deliver more thrust per kilogram when combusted. Moreover, Hydrogen, when made using renewable energy to power electrolysis, only releases Water Vapour (H_2O) into the atmosphere. Although this is still a primary greenhouse gas, it is a far better alternative to the multiple greenhouse gasses released by traditional Jet engines, since Water Vapour only remains in the atmosphere for small amounts of time, compared to Carbon Dioxide which can persist for centuries.

Practical and Logistical Issues of Hydrogen Aircraft:

However, Hydrogen has some difficult logistical problems that aircraft manufactures must face and overcome before it can be used effectively and efficiently in aircraft. Firstly, for Hydrogen to unleash its maximum energy of 120MJ/kg, it must be kept in liquid form at -253^{O}C. To be able to maintain this very low temperature in compressed liquid form; heavy, insulated storage tanks will lead to a complete redesign the aircraft we fly today. Furthermore, the tanks will need to be monitored by advanced systems and temperature gauges to minimise leaks, could be potentially deadly due to the flammability of even tiny volumes of gaseous Hydrogen in the air. Secondly, because Hydrogen cannot be stored in the wings like regular Jet Fuel, but due to its volume and large tanks, it will have to encroach a significant proportion of the cabin area. The problems that arise with this type of plane design means that airlines will not be able to carry as many passengers as usual. For example, if the hydrogen storage tanks consumed a 1/3 of the original aircraft cabin area, airlines would no longer be able to generate profit from the remaining passengers due to the nature of their very slim profit margins – for example, the average airline will only generate profit if the plane is over 80% full of passengers; as the operating costs of fuel, airspace fees and staff are countless. Therefore, I believe that it is unlikely that airlines are going to invest in hydrogen-powered aircraft designs, for example Airbus's Zero-e design due to the decreased range, speed, and passenger volume due to the weight of liquid hydrogen.

Inefficiency of Hydrogen production:

In addition to the above remarks on the issues of Hydrogen storage, Hydrogen is also very inefficient to produce and combust. Firstly, when we convert electricity to create Hydrogen using the method of electrolysis, we already lose roughly 25% of the original energy. Next, when we use Hydrogen for combustion in jet engines, only 30% of it is released as useful energy (as forward thrust for the airplane). This is due to the current inefficiency of the new and expensively modified engines, which are, however, expected to improve over time. Therefore, compared to the original electricity used to make hydrogen, only around 23% is useful energy for the aircraft, the rest is wasted. The cost of wasting all this useful energy is way too much for regular airlines to pay – and Hydrogen adds up to over 16 times higher than the cost of regular jet fuel (as of August 2022). The cost of obtaining large quantities of Liquid Hydrogen is so large because the infrastructure to transport Hydrogen around, in addition to general airport logistics, is unbelievably expensive and requires multiple security measures. Lastly, liquid Hydrogen is very explosive (it can ignite when exposed to very small volumes of ordinary air), which poises safety concerns for the passengers and the driver's transportation it from Hydrogen production facilities to airports. If aircraft manufacturers were to consider using Hydrogen, they would have to spend billions into researching, certifying, and producing safety measures around the usage of this level-4 flammable substance, making it a very unadmirable substance to use. Unless a technological breakthrough is achieved, I think that Hydrogen is very unlikely solution to be used for the current aviation conundrum, as easier and more efficient methods such as blended SAFs are more readily or cheaply available to airlines and shall certainly make a more significant contribution to the conundrum in the short term.

Manufacturing more efficient planes via practical strategies:

The relationship between time and the efficiency of aircraft:

To date, modern airplane manufacturers have made considerable progress in reducing fuel burn, which hence has a direct link to the sustainability of aircraft (in terms of its gaseous emissions, noise, and air pollution figures). Modern aircrafts are around 85% more efficient then very early commercial airliners which entered service in 1960s. For example, the Boeing 707-120B, which was an early commercial airplane seating around 174 passengers had a fuel burn rate of approximately 7,500 Kilograms of fuel per hour, compared to a (fairly) modern Boeing 737-800NG (1994), which is a commercial airliner which can seat around 178 passengers, however it has a far lower fuel burn rate averaging at around 2,800 Kilograms of fuel per hour. This emphasises how far the aviation manufacturing industry has come in reducing fuel consumption by making huge changes in aircraft structure, aerodynamics, technology, and weight-reduction technologies.

Case Study: Airbus's main three strategies to reduce fuel burn of aircraft:

For example, the aircraft manufacturer Airbus has 3 main methods that it has introduced which allowed it to heavily reduce the fuel burn of their most recent aircraft: The Airbus A350. Firstly, they introduced a redesigned airframe that implements lightweight composite materials, which is a unique combination of two or more materials, which show characteristics of strength, while being lightweight that previously used materials. For example, a composite used in the A350 is carbon fibre-reinforced plastic, where microscopic carbon fibres (thin, but strong crystalline filaments of Carbon), are attached to plastic resin. As individual substances, however, they cannot provide the mechanical and thermal properties specifically required for the aircraft's structure, however when combined they easily outperform Aluminium and Iron; being both lighter and far more resistant to corrosion, both reducing overall fuel burn and maintenance. These composites comprise over 50% of the A350's structure – used mostly in the wing and the wing box (the component which connects the wings to the main fuselage of the plane). In statistics, this has allowed the A350 to emit 26% less fuel (5,500 compared to 7,000) burn than its competitor, the Boeing 777 (which has limited composites).

Airbus's second method to reduce fuel burn: re-engineering avionics:

Secondly, Airbus's second method to reduce fuel burn is via re-engineering avionics. For example, it uses reduced thrust settings instead of using full thrust settings, which both reduces noise pollution for surrounding areas and significantly reduces the fuel consumption at the thrust-demanding take-off stage. In Addition, Required Navigation

Performance (RNP) allows pilots and airlines to optimise routes (creating them more direct and using wind speeds to an advantage) and approaches, hence reducing distance, noise pollution and fuel burn. This further works alongside advanced FMS (Flight Management Systems) which control the thrust settings, altitudes, and speeds of the aircraft to ensure optimum fuel burn at all stages of aircraft flight.

Airbus's Third method to reduce fuel burn: development of wingtips:

Lastly, the third method that Airbus is using and evolving, which many other plane manufacturers are all turning to as an efficient method to reduce fuel burn is wingtips. Wingtips on airplanes are designed to minimise the formation of vortices, which are generated due to the pressure difference between below and above the wing (due to different velocities of air), which create significant drag, which increases fuel burn. However, wingtips, such as winglets (Boeing's version of wingtips) or sharklets (Airbus's version of wingtips) are aerodynamic devices fixed onto the end of wings, which smooth the airflow and minimise vortices, reducing the induced drag and improving fuel efficiency. Multiple studies suggest that wingtips result in fuel burn reductions in the range of 3-6%, but as wingtip technology changes, this figure will gradually increase. If we return to the comparison between the Boeing 707 and 737 fuel burns, it is evident that the addition of winglets has significantly reduced their fuel burns, as well as other methods that Boeing has adopted over the decades.

Conclusion:

In conclusion, while the aviation industry has made numerous research achievements and developments in recent years, it is evident that this industry has a long journey ahead to make the skies more sustainable. However, there are promising pathways which will be used to achieve this goal, including the practical and accessible solution of Sustainable Aviation Fuels (SAFs) which are currently being implemented as we speak. Hopefully, with ongoing investigation and research, these will become a more favourable choice for airlines as they reduce in price as the overall demand increases, leading to a substantial decrease in aviation's Carbon footprint. While Hydrogen has attractive statistics associated with its reduced greenhouse gas emissions and potential energy, this method certainly will require more investment, regulation, and careful scientific planning before it is regularly implemented, due to the obstacles of safety, storage, and its overall efficiency. In a journey for more sustainable aircraft, I am confident that aircraft manufacturers will continue to make progressive small, gradual changes to their aircraft's efficiency which will benefit both communities, airlines, and the environment.

As we look into the future, I hope that the collaboration between international governments, airlines, airline manufacturers can be harmonious, and always be directed to improving aviation safety and sustainability for the benefit of all the humans and animals inhabiting our Earth. If we can identify that the aviation industry is a critical leader of global warming, we can reduce its impact and allow people to enjoy the luxury benefits of air travel, without the fear that other people will be affected by their holidays, business trips or leisure.

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