Limited Possibilities to Reduce CO2 Emissions from Aviation due to the Growth in Aviation Demand

Aviation today is deeply embedded in society. Already for a long period of time, demand for aviation has been increasing. This is good news for travelers, who can fly for a relative small amount of money to many destinations all around the world. The growth of the aviation industry is also good news for airport operators, airlines and aircraft manufacturers, as they see their yearly turnover increasing.

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There are also some negative, even adverse, effects of aviation, such as noise, CO2 emissions, which have an impact on climate change, and the usage of finite resources of material and energy. Climate change is currently a hot topic. Aircraft emit the greenhouse gas CO2. Also, aircraft emit this gas at such an altitude, that it will not easily be removed from the atmosphere and, thus, will continue to have an impact on climate change for a relatively longer period of time.

CO2 emission has a strong relation with fuel consumption. There is a strong economic incentive to reduce fuel consumption in aviation. As a result of that, aircraft have become very efficient in their fuel consumption. Flying one aircraft seat costs roughly the same as, or even less than, driving a car, only aircraft have almost ten times the speed of a car.

However, people drive cars for relatively small distances, whereas they fly airplanes over long distances. Therefore, in absolute terms, flights require a lot of fuel, and the result, thus, is a lot of CO2 emission.

The aviation industry heavily relies on new technological developments, in its effort to reduce fuel consumption. Some even suggest that it is not necessary for mankind to change behavioral patterns as engineers are working on new technology that will solve all problems.

It is definitely true that new technologies can make enormous improvements. We have seen this in the past, when new technologies have made very substantial contributions by significantly lowering noise production of engines and airframes, and lowering NOx and CO2 emissions by as much as 80 per cent and 40 per cent over the last forty years. No doubt that in the future, aircraft technologies again will play an important role in reducing undesired effects from aviation activities. But will it be enough? To answer that question we have to look at current technological developments, at the rate at which new technologies replace older technologies, and at the growth rate of the demand for air travel. The assumption is that the total CO2 emissions from aircraft will not rise in the future at least, but that it will be preferably lower.

Aircraft Technological Development

A quick scan of the popular press, scientific literature and the internet reveals many ideas for new aircraft technology. Many of them are promising from an environmentalist point of view, as they are expected to make serious reductions in fuel consumption possible. But which of all these ideas can and should be taken seriously? Which will appear to be nothing more than an interesting idea that can never be turned into a realistic product or prototype? Many ideas are also quite similar and, thus, form some sort of ‘category of potential new technology types’.

Several aircraft technology experts from different aeronautic disciplines were interviewed for this research in order to select serious technologies, and to get a broad scan of possible technologies as well. These experts were asked to present their opinions about the aircraft technology developments which they expected to be serious in their aeronautical discipline and which, according to their opinion, would pure technically speaking be a possibility. This article presents a few of the technologies that came out of this interview round.

One of the ideas is to create economies of scale by making aircraft larger. The currently largest available aircraft, the Airbus A380, can host 550 passengers in a three-class configuration, and up to almost 800 passengers if all seats would be short-pitch economy class. What would be the effect if aircraft would fly around with over 1,000 passengers onboard? A preliminary design study for such an ultra high capacity aircraft showed advantages in terms of costs and fuel consumption (and thus CO2 emission) of roughly 10 per cent per flown seat per kilometer [1]. Disadvantages were also found, ranging from psychological resistance by both potential passengers and crew to fly with so many people together in one plane, to dimensional restrictions as this aircraft would not fit the currently-used 80x80 meter box that forms the largest sized aircraft that an airport can handle. An artistic impression of what such a large aircraft looks like can be seen in figure 1.

Photo 1: *A sketch of a possible ultra high capacity aircraft for 1001 passengers. Source: H.J.K. Lemmen, modification of an Airbus website picture*

Another idea is to combine wing and fuselage in a configuration called Blended Wing Body (see for instance [2]). This configuration leads to one construction both responsible for lift and containing the payload. The parasiting drag of the fuselage (causing drag without adding substantially to the lift generation) is reduced. This configuration is lighter than a conventional aircraft that contains the same number of passengers, and it causes less drag. Therefore, less engine power is needed for propulsion, less fuel per seat-kilometer is used and less CO2 emitted into the atmosphere.

As Blended Wing Bodies form a category, they come in many shapes and sizes. Ranging from flattened and widened fuselages (that, although generating lift now as well, still need a wing-like construction to fly) to fully integrated wing fuselage combinations that look like discs, or like flying wings. Potential reductions in fuel consumption (and thus in CO2 emissions) therefore also differ, ranging from 10-15 per cent to even 50 per cent for the most dramatically changed new designs. The later requiring more technological innovation (in materials, construction and controls), therefore being more risky and expected to be 'technology ready' or prototyped after many more years than the former.

Completely different is the idea of upgrading the traditional propeller to be useful at higher flying speeds. Traditionally, the propeller has a much higher efficiency than a jet engine. The efficiency of slightly accelerating a lot of air appears to be much higher than accelerating a little bit of air with huge speed as the jet engine does. However, jets are capable of accelerating an aircraft to higher flying speeds; the propeller loses its efficiency advantage at speeds of roughly 700 km/h and higher. This is well under the cruising speed of many modern aircraft.

High bypass ratio turbo fan engines combine the power of the jet engine with the efficiency of the propeller by putting a propeller on the engine shaft that, in addition to the high speed jet stream, also accelerates cold air, but not up to such high speeds.

Still, some experts, however, think that by thinning the propeller blades and curving them in certain ways, another efficiency increase of 20-25 per cent can be made on top of the efficiency increase of turbofans over pure jet engines. Wind tunnel experiments in different laboratories settings support this finding. However, experts add that development costs are enormous, and a serious economic incentive (like a very high oil price) should be present for a propeller at high flying speeds to become reality.

Innovations in the materials itself, as well as in the way they are used, are expected to come from the material and construction sciences. New materials, such as composites, are lighter, but with comparable fatigue, strength, buckling and damage tolerance characteristics. Composites can consist of traditional aluminum in combination with fibers, but can also come completely without aluminum and only consist of carbon fibers and epoxy for instance. Both material combinations make it possible to construct large panels, and therefore omit (to various extents) the classical riveted lap joints. The full-fiber materials can be winded and are expected to make the production of vessel-like shapes (like fuselages) possible at once. Serious cost and weight reductions will then be possible. Preliminary studies suggest weight reductions of up to 30 per cent, which will result in fuel consumption reductions of 15 per cent per flown seat per kilometer. Disadvantages are the high-tech way of production that will not be available all over the world, making repairs after damage difficult, as well as the difficulty to detect potential dangerous damages [3, 4].

A lot of other ideas about technologies exist. This article does not intend to give an overview, but rather just some examples to illustrate the role of technology in reducing greenhouse gas emissions from aviation.

Replacement Rate of old Technology

As we have seen, technology can seriously reduce emissions of the greenhouse gas CO2 from aviation. However, when such a technology is developed, it is not automatically available for use in the aviation industry, and, it has not replaced older technology. Until then, the new technology will not contribute to the reduction of CO2 emissions.

Looking at past experiences, the development of a prototype of a new aircraft technology and certifying it for use in aviation takes approximately 10 years. That figure is the minimum amount of time, because it holds true for developments such as the A380, which, although it is much larger and contains many innovations and challenges, basically is a newer version of a conventional aircraft. The aircraft design paradigm of a cigar-like fuselage with halfway two wings and a tail section at the end is as old as the early 1950s (see for instance [5]). Newer design paradigms, like the described Blended Wing Body will take longer than 10 years to develop.

Aircraft are designed to last long. Where the largest share of the car fleet of the world replaces itself roughly every 10 to 15 years, aircraft stay in service for at least 25 or 30 years, and sometimes even longer. That means that an additional 25 years will have past at least before an old fleet of aircraft is fully replaced by newer technology.

These numbers are valid for not-too-extreme changes in aircraft technology. Some of the technological developments as described in section 2, however, require much more than a small change in the aviation system, like the ultra-high capacity aircraft and the blended wing bodies. Our research identified many practical reasons why these innovations would face many more roadblocks prior to implementation (see [2] p.187). Reasons range from lock-in effects at airports (currently not designed to handle larger than 80x80 meter sized aircraft) to potential increases in vortices, so that larger separation times and, thus, airport capacity issues come into play. Handling those roadblocks might increase the effort of implementing these new technologies to such a level that either the implementation time increases or the innovation is not further developed at all.

Several interviewed people (ranging from technology developers to policy experts) pointed at the trade-off between open market ideals and desires to reduce CO2 emission. In their opinion, regulation could, in principle, enhance the development and implementation of new technologies (for instance by stating maximum emission levels, emission trade or enforcing faster replacement of older technology), but at the price of some operators who would have an competitive disadvantage as they cannot afford those new technologies. This serious friction should be readdressed at every stage in time when new technologies are available to further reduce CO2 emissions ([2], p.204).

Combining the numbers means that a new and very good technical idea to reduce emissions of CO2 from aircraft, of which the development starts tomorrow, will only give its full benefit after at least 35 years, or maybe even longer. What will be different in the aviation system by that time? Many things perhaps, but one thing is for sure though: the demand for air travel will have increased.

Growth Rate of Air Travel Demand

The demand for air travel increases every year with roughly 5 to 6 per cent worldwide. Sometimes, incidents like 9/11 or SARS reduce growth rates, but the long-term trend always shows an average annual 5 to 6 per cent increase.

Each year, Airbus and Boeing present a report in which they forecast what the demand for air travel will be in the period between now and 20 years from now (see for instance [6, 7]). Their current publications, forecasting till 2026, roughly follow the long-term growth trend. But 2026 is not within the timeframe for new technology to fully replace an old aircraft fleet as described earlier. For that timeframe, forecasts till 2040 and 2050 are needed.

Many attempts can be found in the literature that extrapolate the past and current growth figures for time frames far beyond 2026. This research did not extrapolate, but has identified a limited set of factors that, according to literature and experts, determine the growth rate and fleet composition ([2], pp.147-164). These factors, as identified, are: GNP, speed of maturation of aviation markets, a development into either a hub-and-spoke system or a point-to-point system and the focus of the tourist industry being either short-haul or long-haul. Several estimates for the value of these four factors resulted in different plausible scenarios for air travel demand in the year 2050. The most pessimistic estimates, taking into account the resistance in Europe and North America to further airport expansions, gave a smallest growth scenario of almost 2.5 times the air travel demand of 2004 in 2050 (see for a discussion of the possibility for air travel demand growth for instance [8]). The most optimistic estimates resulted in a growth figure for 2050 of slightly more than 9 times 2004-levels. The factor model represented the forecasts of Airbus and Boeing for 2026 very well, given assumptions for the value of the four factors.

Can Technology Reduce CO2 Emissions from Aviation?

Clearly, technology can reduce the emissions of CO2 from aviation when measured in kg CO2 per seat flown per kilometer. However, only the total amount of CO2 emitted is important for the issue of climate change, and, full benefits from technologies appear in the very long run. When aviation demand has increased by approximately 250 to 900 per cent in these far points in time (2050), a 15-25 per cent or even 50 per cent reduction in CO2 emissions due to new technology is (by far) not enough to reduce the total CO2 emission of aviation.

As technology can have a share in reducing CO2 emissions, it should not be overlooked. New efforts should be put in developing even better technology that brings CO2 reductions over 50 per cent, and, according to some project suggestions, even 80 per cent.

If, however, society really wants to reduce CO2 emissions, also from aviation activities, in addition to technological developments, many other non technological potential solutions should also be seriously considered. Some ideas mentioned are, among many others, emission trading and enforced replacement of older technology.

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Biography

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