Air transport: efforts are still in the state of experimentation

With regard to climate change, air transport has two major characteristics. First, a strong growth in emissions that the technological and organisational progress is currently unable to contain. Second, international air transport has been excluded from the climate negotiations and the sectors covered by the United Nations Framework Convention on Climate Change (UNFCCC). The file was entrusted to the International Civil Aviation Organization (ICAO) that brings together the dominant players in the sector (manufacturers, airlines). This resulted in a proposal for the long-term management of air transport emissions: the CORSIA scheme for "*Carbon Offsetting and Reduction Scheme for International Aviation*".

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SUMMARY

1 • AIR TRANSPORT EMISSIONS ARE STEADILY INCREASING

When calculating emissions from the air transport sector, international transport emissions (530 million tonnes of CO_2 equivalent in 2015, i.e. approximately 60% of the total) and those from domestic transport (345 million tonnes of CO_2 equivalent or 40%) are always differentiated. The temporal dynamics of these emissions are the result of the growth of air transport and the improvement of its energy efficiency.

	2015
international aviation	
World	529.69
Europe	136.08
France	17.78
National aviation	
World	345.44
Europe	18.98
France	3.64

TABLE 1. DOMESTIC AND INTERNATIONAL AVIATION EMISSIONS IN 2015 (MTCO2E)

Source: International Energy Agency (IEA), Enerdata

International aviation is a driver of emission growth. Between 1990 and 2015, its emissions increased by 104.6% worldwide, 88.1% in the European Union and 88.8% in France (AIE, 2017, p.109). **At the global level, emissions from domestic aviation are growing three times slower than international aviation emissions (+ 15% between 2000–2017) (Enerdata)**

In Europe, these emissions remained stagnant and even decreased in France by 13% between 2000 and 2016 (source Enerdata), probably because of the increased use of the high-speed rail. The European Union accounts for 26% of international aviation emissions and 5.5% of domestic aviation emissions, which is easily explained by the small size of the member countries. France accounts for 13% of European emissions from international aviation and 19% from domestic aviation, which reflects both the lower propensity to travel abroad (tourist trips) compared to the countries of Northern Europe and the size of the country (1,000 km of diagonal distances across the "Hexagone"), favouring certain domestic links by plane.

	Unit	2015	2016	2017
European Union		**$MtCO_2$**	**18,9757**	**19,8323**
North America	$MtCO_2$	172.8483	179.9023	188.1661
Latin America	$MtCO_2$	15.5112	14.6124	14.5108
Asia	$MtCO_2$	94.0161	101.2096	103.9358
Pacific		**$MtCO_2$**	**10.1798**	**10.9321**
Africa	$MtCO_2$	8.4273	8.1547	8.3436
Middle-East	$MtCO_2$	4.0618	4.117	4.0657
World	$MtCO_2$	345.4379	359.9141	371.7467

TABLE 2. DOMESTIC AVIATION GREENHOUSE GAS EMISSIONS BY REGION

(Source: Enerdata)

The radiative forcing of aviation

The figure of aviation's contribution to anthropogenic CO_2 emissions of around 2% is frequently put forward; it can be discussed for two reasons:

- An alternative calculation results in less optimistic figures. According to the International Energy Agency, in 2015 aviation accounted for 7.5% of world oil consumption, or 288 Mtoe (excluding ground fuel use). By multiplying it by the Base Carbone ® coefficient of Ademe (3,642 tCO_2/toe) which includes emissions from extraction, transport and refining, we obtain a figure of 1,049 million tonnes of CO_2, i.e. 3.2% of global fuel emissions (32,294 million tonnes in 2015). In addition to CO_2, aviation produces in-flight nitrogen oxides that are not greenhouse gases but are the precursors of ozone, which is a potent greenhouse gas with a short life span on the one hand, and on the other hand, it contributes to the destruction of methane, which has the opposite effect of cooling. The net result is a warming effect.

Especially, at very high altitudes, planes produce contrails that can turn into cirrus clouds. These clouds are formed at very cold temperatures (-40°) in very high humidity and are also dependent on the dust emitted by the combustion of kerosene(Kärcher, 2018). The issue of their contribution to global warming has long been known (Penner, Lister D.H., Griggs D.J, Dokken D.J, & M., 1999); existing evaluations show that this contribution is important, but they present a very high margin of uncertainty. This was the pretext for excluding this issue from the discussions on aviation's contribution to climate change, thereby minimising its impact.

However, it should be noted that cirrus clouds have a short life span: if the flights stop, the effect disappears within 24 hours unlike CO_2 whose life span is one hundred years or more. There are ways of reducing cirrus clouds, the main one being the reduction of combustion dust (the use of biofuels could be useful in this respect), which could decrease the formation of these clouds ten-fold (Kärcher, 2018).

The estimate by a group of researchers (Lee et al., 2009) shows an aviation contribution to global warming of 4.9% in 2005 (with a 90% probability of being placed between 2% and 14%).

TEXT BOX 1

2 • INSTITUTIONAL AND POLITICAL RESPONSIBILITY FOR AVIATION EMISSIONS: THE ICAO PROPOSAL

• THE SCHEME • The UNFCCC has excluded international air transport emissions from targets set for the countries because of the difficulty in allocating them. National emissions may be included in the voluntary national contribution (Art. 31)[1] . Already in 1992, the Kyoto Protocol specified that Annex I countries should continue to limit emissions of gases not covered by the Montreal Protocol. The International Civil Aviation Organization (ICAO) has been in charge of the file since 1998 in addition to its usual tasks (management of conventions between countries, security, etc.) However, there is a clear gap between the UNFCCC's mission to reduce greenhouse gas emissions and ICAO's mission to protect and promote international aviation (Lyle, 2018).

By the end of the Kyoto Protocol period (2012), ICAO had made little progress in establishing mechanisms for managing international aviation emissions. It set targets: a voluntary energy efficiency improvement of 2% per annum and carbon-neutral aviation growth from 2020 consisting in the use of economic tools, technological and organisational progress and the use of alternative fuels. In parallel with ICAO, the International Air Transport Association (IATA) had a fairly similar outlook with an emission reduction target of 50% in 2050 compared to 2005 levels (Bows-Larkin, 2015). **Starting in 2013, ICAO began to clarify its intentions: to use a market mechanism and tradable emission permits, biofuels and to set new technical standards for aircraft starting in 2016.**

During this period, the European Union advocated for territorialised measures and eventually included aviation in its emission trading system (EU-ETS).

Failure of the European ETS against the opposition from China and the United States

The inclusion of aviation in the European emission trading system (EU-ETS) entered into force in 2009. The global allocation for European Union internal and external air transport was then set at 95% of the average emissions for the 2004–2006 period. All flights departing and arriving within the European Union were taken into account.

In 2009, airlines and airline associations based in the United States and Canada brought forward an action for the annulment of the United Kingdom's transposition of the EU Directive. The English court referred this to the Court of Justice of the European Union (CJEU), and the Advocate General of the CJEU gave unfavourable conclusions to the airlines in early October 2011. Far from easing tensions, these conclusions foreshadowing a defeat for the airlines have raised the tension even more: two weeks later, the House of Representatives passed a bill prohibiting US airlines from complying with European regulations. In early November 2011, the International Civil Aviation Organization (ICAO) Council adopted a position urging the EU and its member states to refrain from including airlines based outside the EU in the EU-ETS. This was a move that triggered a strong reaction from Connie Hedegaard, the European Commissioner for Climate, and the Association of European Airlines (AEA) who lamented a disappointing political position. China and India have also vigorously opposed the inclusion of aviation in the European carbon market, denouncing the political and economic decision against them. However, the Chinese Academy of Social Sciences, while recommending Chinese airlines to take legal action against the EU, also urged them to limit their CO_2 emissions by using biofuels, improving the efficiency of engines and optimising airlines. As a result of these pressures, the field of application of the EU-ETS was restricted to flights within the European airspace and the allocation was reduced accordingly. 82% of emission permits were distributed free of charge, 15% auctioned and 3% allocated to a reserve for new operators on the market. For the reasons

1 - At COP 21 in Paris, the part of the text relating to air and maritime emissions was withdrawn during the negotiations. This issue therefore continues to be managed by ICAO. However, the climate negotiations have taken a bottom-up approach, with the countries setting their contribution via the "INDC", quite in opposition to the top-down approach of ICAO consisting in developing standards to be applied by all parties.

of compatibility, the European Community has proposed the indefinite retention of flights from or to the European Economic Area outside of the EU-ETS, which results in a shortfall in reducing emissions of approximately 1/3. In addition, for intra-European flights, the Community proposed to align the requirements for aviation with those of other sectors, which amounts to a reduction in permits of 2.1% per year from 2021.

TEXT BOX 2

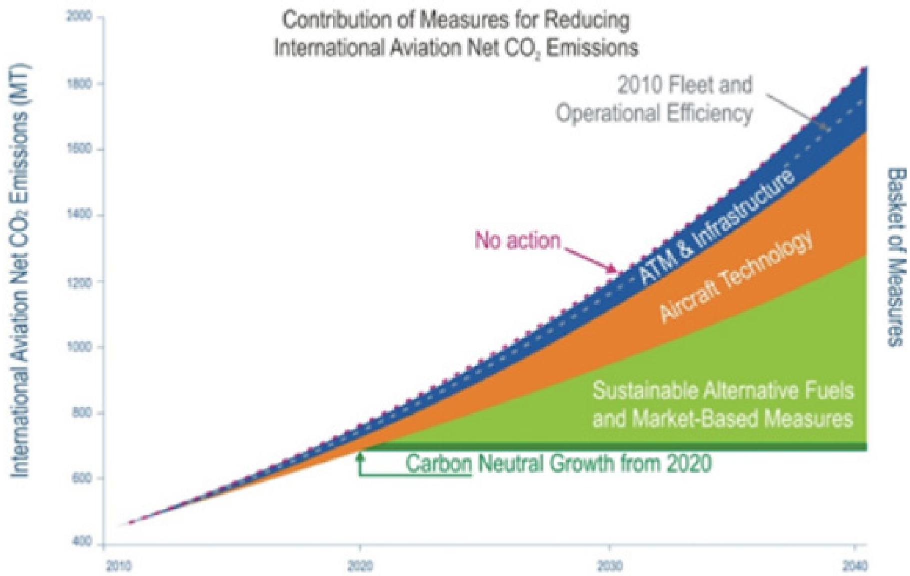

FIGURE 1. AO'S VISION FOR REDUCING EMISSIONS

Source: ICAO, 2013

The emissions estimated by ICAO in its forecast of the distribution of measures for the reduction of net CO_2 emissions due to international aviation are those of the airlines for each journey they make. In particular, this principle results in circumventing the principle of "common but differentiated responsibilities" between countries fundamental in international climate negotiations but contradictory to the equal treatment by ICAO. The responsibility for monitoring, reporting and verification (MRV) of the international airlines rests with the individual countries. Beyond MRV, an important carbon offsetting and reduction scheme (CORSIA) is being carried out by ICAO which plans to keep a consolidated register.

• CORSIA • In October 2016 after several years of discussions, the air transport sector signed a future emissions management plan called CORSIA (Carbon Offset and Reduction Scheme for International Aviation) developed by the Committee on Aviation Environmental Protection (CAEP) composed of country representatives and private sector experts who play a leading role (Lyle, 2018). CORSIA is a global scheme of market-based measures designed to offset CO_2 emissions from international aviation in order to stabilise their levels starting in 2020 (CNG2020). The draft standards and recommended practices (SARP) and related guidance material form the "CORSIA Package" to help offset CO_2 emissions through aircraft operators acquiring and cancelling emission units from the global carbon market.

For this, every three years, ICAO member countries participating in CORSIA must verify that their aircraft operators comply with the CORSIA offsetting requirements in addition to the MRV of annual CO_2 emissions. The plan includes a pilot phase starting in 2021 until 2023 and a first operational phase from 2024 until 2026. These two phases rely on the voluntary participation of the countries. Finally, there is a phase of full application from 2027 until 2035 including all countries whose individual share of international aviation activities in 2018 is greater than 0.5% of the world total or whose cumulative share accounts for 90% of the world total. **The least developed countries, small insular developing countries and landlocked developing countries are exempted from this scheme unless they voluntarily join it. These numerous ICAO exemptions mean that this agreement to reduce emissions from the international aviation sector ultimately cover only approximately 75% of emissions(Lyle, 2018, p.110).**

Calculation procedure for emission offsets required from operators under the CORSIA system

The quantities of CO_2 to offset is calculated according to the following formula:

Annual emissions of operator x, growth factor = amounts of CO_2 to be offset

The growth factor in this equation changes each year according to the growth of emissions of each sector and each operator. The growth factor is calculated by ICAO based on the percentage increase in the quantity of emissions from the base year to a given future year. This calculation of the offsetting requirements to be allocated to the different airlines will go through different phases. Over the 2021–2029 period, this factor will be indexed only on the growth factor of the emissions from the sector. The objective is to gradually move to a factor calculation based solely on the evolution of emissions of the operators.

After this calculation, the operator reports on the use of sustainable airplane fuels during the compliance period. The government therefore deduces the benefits of using sustainable aviation fuels and informs the operator of its final offset requirements for the compliance period. Finally, the operator submits a validated emission unit cancellation report to the government that it verifies by informing ICAO.

Source: ICAO, Presentation of the CORSIA scheme, 2018

TEXT BOX 3

The position of the European Union concerning the ETS system was first to wait for the implementation of the international CORSIA management plan and to take timely measures to adapt to it. An assessment of the effects of CORSIA for the European Economic Area accompanied the study of the implementation of the EU-ETS. The following table shows the main features of CORSIA and EU-ETS; it highlights the gap in ambition and the problems of compatibility between the two systems.

CORSIA	EU ETS
Unlimited growth	Scalable ceiling
Nothing on emissions below the 2020 level	Total coverage of emissions, with a "temporary" exclusion of aviation to or from locations outside Europe
Partial coverage of emissions (exceptions)	
Completely based on offsetting	Excludes offsetting starting in 2020
Offsetting criteria currently unknown	List of what cannot be retained as offsetting
Voluntary until 2027	Binding
Absence of sanctions	Financial penalties

TABLE 3. DIFFERENCES BETWEEN CORSIA APPROACH AND EU EMISSION TRADING SCHEME

Source: Adapted from Carbon Market Watch, 2017

Similar to the EU-ETS, the establishment of the CORSIA system is questionable. There are many differences of opinion between ICAO and other non-state actors on the subject of reducing emissions from the international aviation sector, which shows the complexity of the positions of each of the actors with regard to the possible actions

• THE POSITION OF THE PLAYERS WHEN FACING LARGE OFFSET SYSTEMS • Manufacturers and airlines intervene through various associations whose aim is to provide expertise in the debate on methods to reduce CO_2 emissions in the aviation sector. The main associations are ATAG and ACARE[3] on the manufacturers side and IATA for airlines. These actors have certainly played a decisive role in the rather opaque development process of the ICAO proposals, and they absolutely adhere to a strategy of using biofuels and an offsetting system for the remaining emissions. Their communication highlights expected technological and organisational changes. For example, they state a 75% reduction in passenger CO_2 emissions by 2050 compared to 2005 levels (source ACARE)[4]. An objective to be adhered to in the context of increased development of global air traffic. In fact, in October 2018 IATA planned a doubling of global air traffic by 2037.

However, according to the 2016 Carbon Market Watch annual report, CORSIA's maximum contribution to the reduction of aviation emissions is estimated to be 0.3 GT of CO_2 **equivalent per year, while the extra emissions from the sector should be around 0.6 GT in 2030 compared to 2017 levels.** The International Coalition for Sustainable Aviation (ICSA)[5] published a report in February 2018 entitled "*Understanding the CORSIA scheme: a critical guide to the key provisions of the draft standards and recommended practices and related guidance material for the carbon offsetting and reduction scheme for international aviation (CORSIA)*", in which it gives a critical opinion on the implementation of this system and on several elements of its functioning.

First, it considers that CORSIA's monitoring, reporting and verification (MRV) system as proposed in the CORSIA Package is not transparent enough. For ICSA, allowing third parties to access reports on emissions submitted by airlines would help to ensure the environmental integrity of CORSIA and avoid market distortion by deterring any preferential treatment of transport companies. In addition, the coalition suggests that ICAO refrain from awarding credits to alternative aviation fuels under CORSIA as long as the provisions on sustainable aviation fuels including sustainability criteria have not been strengthened. According to ICSA, these strict and comprehensive sustainability criteria should be included in the final implementation elements of CORSIA before the launch of the 2021 pilot phase.

• SWEDEN, THE PIONEER IN TAXING FLIGHTS • In Sweden, a law passed on 30 November 2017 introduced an aeronautical tax starting on 1 April 2018. The Swedish government requires airlines to declare and pay tax on all commercial flights departing from Sweden, chartering aircraft with more than 10 seats. The tax rate depends on the final destination of the passenger: €6 to continental Europe, €25 to countries outside Europe (Middle East, Africa, USA, Central Asia), and €40 to other countries. The law provides for exemptions for children under 2 years of age, crew members on duty, flights following a technical stop, flights returning to the airport for weather reasons or following a mechanical failure.

The consequences of introducing this tax were very quickly felt. **On 1 October 2018, the Swedish transport agency lowered its air traffic forecasts for 2018 and 2019 by 500,000 passengers compared to the forecasts published in the spring of 2018. The number of passengers departing from Swedish airports should therefore only increase by 1.3% in 2018, totalling 23.7 million passengers, and 2.3% in 2019 (totalling 23.9 million passengers)**. External traffic is expected to increase, while domestic traffic is expected to decrease. The Swedish transport agency has attributed the relatively small

3 - https://www.acare4europe.org/sites/acare4europe.org/files/document/volume1.pdf
4 - https://www.acare4europe.org/documents/delivering-europe%E2%80%99s-vision-aviation-sria-2017-update
5 - The ICSA is comprised of the Aviation Environment Federation (AEF), Carbon Market Watch, Environmental Defense Fund (EDF), the International Council on Clean Transportation (ICCT), Transport & Environment, and WWF.

increase in the number of passengers to the Swedish air transport tax, which came into force in April 2018, and the bankruptcy of Nextjet, the main regional airline, which has led to a reduction in supply, particularly in the domestic aviation market. Moreover, following the implementation, the airlines reacted strongly via IATA, warning that in the short term, this tax would cause the loss of 7,500 jobs in Sweden and would have a negative impact on Sweden's economic competitiveness, with the sector currently accounting for 4% of the GDP and 240,000 jobs in the country. It should be noted that IATA did not refer to the 1944 Chicago Convention, the reference document for the regulation of international air traffic which gave rise to the creation of ICAO, stating that the fuel contained in the tank of an airplane cannot be taxed upon arrival in a country. This agreement is regularly used to prevent any taxation of kerosene.

3 • VOLUNTARY OFFSET SYSTEMS

Environmental protection NGOs and small companies specialising in sustainable development consulting are seeking to produce and sell "carbon credits" to companies not covered by the Kyoto Protocol. **This market mechanism is called a voluntary carbon offset market. These promoters are therefore seeking companies in various sectors that do not have a legal obligation to invest in offset services for their GHG emissions (Valiergue, 2018).** Some of them even extend their proposals by promoting categories of projects not listed by the UN as potentially producing carbon credits, for example selling improved ovens or distributing water filters. Establishing this voluntary offset market is based on the implementation of various systems and practices that monetise these carbon offsetting services. As such, many economic players implement support services for voluntary carbon offsetting by customers during their purchases, particularly in the tourism and aviation sector.

• VOLUNTARY OFFSET PUT IN PLACE BY AIRLINES IN SUPPORT OF LABELLING • Ryanair offers customers the option to check an option when buying their ticket to "*donate to offset the carbon footprint of my flight and contribute to other environmental initiatives*". Meanwhile, Air France sends an email to customers after a flight to promote its "*Trip and Tree*" initiative. Consumers can also choose to go directly through private organisations or specialised NGOs to monetarily offset the carbon emissions of their travels. The principle is always the same: after calculating the carbon equivalent of the trip, the total is converted into a sum of money which the passengers can pay to an association of their choice who will use it to plant trees, for example. Labelling becomes an essential tool so that the consumers can find their way around the multitude of offsetting offers.

Evaluation differences in calculating the offsetting needs when buying a plane ticket

As part of a news story, in October 2018 the French newspaper Libération tried a test ticket purchase for a direct ticket between Paris and Cape Town, South Africa, on several platforms integrating calculators. It is deduced that a passenger in economy class consumes:

- The equivalent of 932 kg of carbon if we trust the Air France calculator;
- 1.735 tonnes according to the German atmosfair.de, which also considers the aircraft model;
- 1.8 tonnes of CO_2 according to myclimate.org;
- 1.98 tonnes according to CO_2solidaire.org, climatmundi.fr and greentripper.org;
- 2.05 tonnes on GoodPlanet.org (the Yann Arthus-Bertrand foundation);
- 2.31 tonnes based on CO_2balance.com;
- On the website of the French Ministry of the Environment (MTES) (Directorate General of Civil Aviation), Cape Town is not listed as a destination. However, a consumption of 891 kilograms of CO_2 equivalent is indicated for a flight between Paris and Johannesburg (South Africa).

In conclusion, the various calculators differ by a multiple of 2.5 in their consumption estimate for the same flight, which adds to the uncertainty as to the effectiveness of the voluntary offsetting actions, and it causes a loss of readability for consumers.

Source: Libération, 20/10/2018

TEXT BOX 4

An operator's membership in an international label therefore appears as more beneficial. Commonly recognised as the most successful, the Gold Standard was created in 2003 at the initiative of international NGOs WWF, SouthSouthNorth and Helio International. It is considered to currently guarantee the best traceability of offsetting projects. Other labels also position themselves as references, such as the "VCS" created in 2006 and adopted by Caisse des Dépôts for the creation of its carbon credit registry in March 2009.

In addition to the labels, project selection remains paramount. For example, reforestation projects are highly controversial, to the extent that Climat Mundi (a consulting firm specialising in supporting economic and institutional players in integrating climate issues and emission reduction into their development policies) is refusing to finance it. Currently, the two main problems are the difficulty of evaluating the amount of carbon stored in a forest and the diachrony between CO_2 emitted by humans and effective offsetting by a forest of at least thirty years.

• TOUR OPERATORS ALSO RELY ON VOLUNTARY OFFSET LABELLING • Tour operators are also mobilising to promote voluntary offsetting to their customers. The ATR (Acting for Responsible Tourism) label, entirely renewed in 2015, wanted to open up to major operators demonstrating that sustainable tourism should not be confined to a niche. Until now, the airlines were invited to determine their annual carbon footprint based on the choice of offers offered to their customers. To go further, the management of the ATR label has announced a proposition that starting in the second half of 2018, 100% of the emissions from airlines shall be offset. The argument put forward by the label is that it seems indispensable that instead of asking for voluntary offsetting from their customers, the airlines themselves must be proactive on the issue. Some companies already operate with this change such as the travel agency Les Ateliers du Voyages (Travel Lab group), which has the ATR label, which for example, on the occasion of the World Responsible Tourism Day on 2

June offset the carbon of all the trips sold that week. This approach was based on a partnership with the CO_2 Solidaire platform of GERES that was launched in 2004 and is currently serving four project leaders (GERES, Initiative Développement, Microsol and Bleu-Blanc-Cœur) with the aim of offering carbon credits with high social quality and direct distribution.

Impact of the development of global tourism on the aviation sector

A study published in May 2018 in Nature Climate Change (Lenzen & al., 2018) states that tourism is responsible for approximately 8% of global GHG emissions. Between 2009 and 2013, the carbon footprint of the sector at the global level increased from 3.9 to 4.5 billion tonnes of CO_2 equivalent considering transport-related emissions and also those resulting from the consumption of goods and services by tourists and business passengers. Given the estimated strong growth of the world tourism sector corresponding to +7% over 2017, the authors of this study conclude that tourism will continue to constitute a growing share of global GHG emissions in the coming years and therefore will increase travel needs, especially air travel. Most of these emissions come from high-income countries because of domestic travel (supported by the development of low-cost domestic flights) but also because of their nationals traveling abroad.

TEXT BOX 5

Other tour operators were also interested in the subject in the early days, such as the Voyageurs du Monde company. Since 2007, the tour operator has offset 100% of its employees' emissions and up to 20% of those of its customers with reforestation programmes through the "*Insolite Bâtisseur Philippe Romero*" foundation. Since 1 January 2018, the group has gone even further by covering 100% of the CO_2 emissions generated by air and ground transport for each trip made by Voyageurs du Monde and Terres d'Aventure. In total, this measure costs approximately €500,000 per year for Voyageurs du Monde and €200,000 for Terres d'Aventure. This is an important choice for the two companies which will replace voluntary offsetting on the part of their customers, which they consider to be inefficient. Others have developed hybrid offsetting systems: 50% of the amount of the carbon offset is provided by customers, and the tour operator pays the remainder to finance energy-efficient tools and equipment in developing countries in partnership with NGOs and local associations. The tour operator Double Sens has implemented this system of traveller commitments in its projects from 2017 and gained interesting results with 30% of travellers participating in the voluntary offsetting process.

4 • TECHNOLOGICAL CHOICES

As part of the preparations for the COP 21 in Paris in 2015, aircraft manufacturers made commitments alongside the world's major airlines to significantly reduce the CO_2 emissions due to the engines from their production lines. **In a letter of commitment issued by the Air Transport Action Group (ATAG), 28 leaders of the main commercial aviation manufacturers, engine manufacturers and airline trade groups and airports have pledged an annual 1.5% improvement in global fleet energy efficiency, carbon-neutral growth from 2020 and a 50% reduction in CO_2 emissions by 2050 compared to 2005 levels.** To comply with this roadmap, manufacturers and companies are working on three major axes: reducing the weight of planes, new engine technologies and alternative fuels instead of kerosene. Developments in airport infrastructure and companies' directives for ground crews also make it possible to participate in the effort of the sector.

• ENGINES • Aircraft construction companies, particularly the two largest companies worldwide – Airbus and Boeing – rely on a series of engine manufacturers. Two major competing companies

– one French-American (CFM International) and the other American (Pratt & Whitney) – compete for the world market. Their numerous collaborations, notably with Airbus, resulted in 2016 in the delivery of 68 A320neo aircraft including the first model with LEAP-1A engines delivered to the Turkish company Pegasus Airlines.

With the A320neo, Airbus gained a 15% reduction in fuel consumption per seat as soon as it was commissioned and 20% by 2020 compared to the current A320 model. As a result, CFM International's engine gives the operators a two-digit improvement in fuel consumption and CO_2 emissions compared to the best CFM engines in service, as well as a reduction in nitrogen oxide emissions and noise pollution. CFM International, the 50–50 joint venture between General Electric (GE) and Safran, has planned to deliver approximately a hundred LEAP engines in 2016, then 500 in 2017 and 1,200 in 2018.

There were more than 11,100 orders and purchase intentions for the LEAP engine at the end of July 2016 (compared to 8,400 GTF from P&W in mid-December). According to the manufacturers, the set of used technologies will lead to an optimisation of the operating conditions combined with the reliability and low maintenance costs of the CFM engines. According to Safran, they will allow greater fleet availability, increased longevity and will help reduce costs and maintenance operations.

The era of hybrid electric engines opens for the aeronautical sector

A hybrid electric propulsion aircraft will fly in 2020. This commitment was made in December 2017 in a tripartite agreement between Airbus, the engine manufacturer Rolls-Royce and German company Siemens. This cooperation completes the agreement planned in April 2016 between Airbus and Siemens to develop hybrid electric engines for airplanes, helicopters and drones by 2020. Industrialists are relying on a project called E-Fan X to design a plane that is less dependent on fossil fuels in order to meet the global objectives of reducing CO_2 emissions. This programme replaces the E-Fan, a two-seat aircraft equipped with a 100% electric engine which Airbus had abandoned in March 2017.

Within this project, along with Airbus responsible for the global integration of the hybrid propulsion system and batteries, Rolls-Royce will develop the turbine engine, the two-megawatt generator and the power electronics. Siemens will supply the electric motors and their electronic power control unit as well as the inverter, the DC/DC converter and the power distribution system.

The E-Fan X aircraft is scheduled to fly in 2020 after a full set of tests on the ground. It will be a BAe 146 test aircraft with one of the four reactors replaced by a two-megawatt electric engine. Subsequently, arrangements will be made to replace a second turbine with an electric engine once the maturity of the system has been demonstrated, as specified by the three manufacturers involved.

Source: Airbus Newsroom, 2017

TEXT BOX 6

• **BIOFUELS** • During the preparations for the Paris climate agreement, aircraft manufacturers have highlighted the importance they attach to biofuels, potentially reducing CO_2 emissions by 50 to 80% compared to fossil fuels, with the establishment of "*sustainable aeronautical biofuels*" sectors. **In the context of mass utilisation of biofuels, industry players and ICAO member countries have identified a set of measures for the deployment of sustainable alternative fuels of the "drop-in" type** (fuels with a chemical structure analogous to fossil fuels facilitating their incorporation in large quantities). The integration of alternative fuels in the pilot phase of the CORSIA carbon offset system in 2021 is already planned. Moreover, in the next version of the Renewable Energy Directive expected in 2018, Europe plans to integrate the aviation sector into the ENR8 objectives of the transport sector. Meanwhile at the end of 2017, the French government signed a public/private partnership in the form of a commitment for green growth (ECV) about establishing a sustainable aerospace biofuels sector in France from waste biomass.

Based on the first test of an airplane that flew on biofuel in 2008, IATA launched its Sustainable Aviation Fuel (SAF) programme in 2011 expecting that 100,000 flights would be flown using biofuel by 2017 and that approximately one million flights would be affected in 2020. Eventually, the projection leads to 1 billion passengers potentially travelling on biofuel flights in 2025. Achieving this goal assumes the creation of many bilateral commitments between producers and airlines and sometimes also manufacturers in the coming years. **Since the first partnership was declared in 2009, these commitments have multiplied and counted 28 in total between 2010 and 2015 involving regional stakeholders** (IATA, 2015). The flight of Hainan Airlines on 21 November 2017 was made using biofuel manufactured by the local unit of Sinopec Group, a Chinese petrochemical company. China made its first transoceanic flight from Beijing to Chicago using green fuel and carrying 186 passengers and 15 crew members. The Boeing 787 aircraft flew on biofuel produced from used cooking oil supplied by China Petroleum and Chemical Corp., a subsidiary of Sinopec Group based in Ningbo, Zhejiang Province. The manufacturer and the company welcomed this success; however, the biofuel used in this case was composed of only 15% cooking oil and 85% conventional aviation fuel.

Although a number of airlines have signed biofuel purchase agreements, the results do not match the ambitions envisioned by IATA. Based on $51 to $55 per barrel of fossil fuel, the use of biofuel accounted for an additional cost of approximately 27% for airlines in 2017 (US Department of Energy, 2017).

The SAS and Preem agreement for the use of biofuel

In Sweden, SAS, an airline, and Preem, an oil company, have signed a letter of intent for an agreement to produce and use renewable aviation fuel. SAS aims to replace the current domestic aviation fuel volume with biofuels by 2030. This letter of intent notifies that SAS and Preem intend to collaborate to jointly produce biojet (renewable aviation fuel or biofuel) as part of the planned expansion of Preem's capacity at the Göteborg refinery. The preliminary start of production will begin in 2022, and the total capacity of biofuels is estimated at over one million cubic metres of which a subset can be biojeted on the plane.

TEXT BOX 7

In order to boost the development of the initiatives, the ICAO secretariat published a very large-scale proposal for the use of biofuels ahead of its top-level conference on alternative fuels in Mexico from 11 to 13 October 2017. **The proposal involves 5 million tonnes of biofuels per year used by airplanes by 2025 corresponding to 2% of projected aviation fuel use; 128 million tonnes per year used by 2040 representing 32% of projected aviation fuel use; 285 million tonnes per year used by 2050 corresponding to 50% of projected aviation fuel use. However, beyond the quantities of production and consumption, the quality of the biofuels used is an important issue not only in terms of fuel efficiency but also in terms of environmental impact and reduction in the use of conventional fossil fuels**. Six aeronautical biofuels are already certified by ASTM (*American Society for Testing and Materials*) for use in combination with fossil kerosene, and several new technologies are being certified.

Les technologies biocarburants aéronautiques certifiées ASTM en juin 2018. Source : ANCRE

Technologies certifiées	Ressources biomasses	Taux de mélange certifié	Maturité technologique	Principaux acteurs impliqués sur l'ensemble de la chaîne (dont **industriels** et acteurs R&D français)
HEFA (1) Hydrotraitement d'huiles	Huiles végétales, huiles usagées, graisses animales, huiles microbiennes	50 % vol.	**TRL9** : Technologie mature dont usine Total en cours d'ouverture à la Mède (France)	**Axens, Total,** IFPEN Neste (Finlande, Pays-Bas, Singapour), UOP-ENI (Italie, USA)
HEFA (1-bis) Hydrotraitement d'huiles	Idem HEFA (1) en coprocessing avec des résidus du raffinage	5 % vol.	**TRL9** : Technologie mature	Idem HEFA (1)
FT-SPK (2) Gazéification & Fischer-Tropsch	Biomasse lignocellulosique	50 % vol.	**TRL8** : Fin du programme R&D BioTfueL en France en 2019	**Bionext (BioTfueL),** IFPEN, CEA, **AVRIL** BELT (Canada), Fulcrum (USA), RedRock (USA), Velocys (USA)
FT-SPK (2-bis) + aromatiques	Biomasse lignocellulosique	50 % vol.	Démontré sur ressources fossiles **TRL7** à partir de biomasse	Idem FT-SPK (2)
SIP (3) Farnesane par voie biologique	Sucres issus de plantes sucrières, Sucres lignocellulosiques	10 % vol.	**TRL9** :Technologie mature à partir de canne à sucre au Brésil, **TRL4** : R&D sur voie lignocellulosique	Amyris (Brésil) en partenariat avec **Total et Airbus** pour l'importation
ATJ (4) iso-butanol ou éthanol	Sucres issus de plantes sucrières, Sucres lignocellulosiques	50 % vol.	Technologie mature pour la production d'alcool, **TRL7** sur la chaîne complète, **TRL4** à démontrer sur biomasse lignocellulosique	GEVO, Lanzatech, Byogy (USA) Ethanol lignocellulosique : **Procethol2G (Futurol),** INRA, IFPEN, **ARD, Lesaffre.** Biochemtex (Italie), Clariant, Poet-DSM (USA), Praj (Inde)

(1) Hydrotreated Esters And Fatty Acids ; (2) Fischer-Tropsch - Synthetic Paraffinic Kerosene ; (3) Synthesized Iso-Paraffins ; (4) Alcohol To Jet.

FIGURE 2. ASTM CERTIFIED BIOFUEL TECHNOLOGIES AS OF JUNE 2018

Source: ANCRE, June 2018

In its report from October 2017, the NGO Biofuelwatch warned about the economic and environmental sustainability of the massive use of ASTM-approved biofuels (Biofuelwatch, 2017). Among these, HEFA is an aviation fuel derived from refined hydrotreated vegetable oil, involving the use of hydrogen (HVO process). It is a special type of HVO for aviation that is slightly different from HVO diesel used as fuel for the road sector. In its report, Biofuelwatch pointed out that HVO fuels, and specifically HVO diesel fuels, experience a huge increase in production. The NGO fears that this new market will create a growing demand for vegetable oils and especially palm oil. **Exponential increate in the use of HVOs in aviation under the pretext of reducing carbon emissions from the sector could thus provoke an additional massification of oil palm cultivation, leading to further deforestation – current surfaces cannot suffice to satisfy all demands for food and fuel**.

• AIRPORTS • Faced with the challenges of reducing the carbon emissions of the sector, airports also make commitments to support the necessary transition. According to the UNFCCC, there were 250 airports in 68 countries in October 2018 (out of 3,864 commercial airports worldwide) with climate change commitments and 44 of them already achieved climate neutrality as part of the Airport Carbon Accreditation programme run by the Airports Council International (ACI). 48 airports joined the programme in the 12 months leading to May 2018 – an increase of 25% from the previous year. In total, this covered 3.3 billion passengers last year, which represents 44.2% of global passenger traffic according to Airport Carbon Accreditation (ACA). ACI World is currently examining various options to ensure that airports around the world officially join the programme.

ACI identifies different sources of emissions by field of application for which airports must take action (ACI, 2009):

• Field of application 1: Sources owned or controlled by the airport. Power plants (heating, air conditioning and electricity production), vehicle fleet (passenger transport, service vehicles, machines used airside and landside), airport maintenance (cleaning, repairs, green spaces, etc.), handling and maintenance of aircraft on the ground, emergency energy, training in firefighting, waste treated on site.

• Field of application 2: Off-airport electricity production purchased by the airport operator.

• Field of application 3: Other activities and sources linked to the airport

Between July 2016 and July 2017, the airports that reported their emissions to the Airport Carbon

Accreditation platform reduced their CO_2 emissions by 202.8 $MtCO_2$, which is a lower result than in previous years (206 $MtCO_2$ in 2015–2016 and 212.4 $MtCO_2$ in 2014–2015).

Airport Carbon Accreditation programme of ACI

The Airport Carbon Accreditation programme run by the Airport Council International is managed independently, approved by the institutions and given support by UN Climate Change, UN Environment, the International Civil Aviation Organization, the US Federal Aviation Administration and the European Commission. To date, airport commitments being voluntary, 39 airports in North America, 17 in South America, 136 in Europe, 47 in the Asia-Pacific region and 10 in Africa carry this certification.

ACI issues four levels of accreditation covering all stages of carbon management:

- Level 1, Inventory: an inventory of sources and annual quantities of CO_2 emissions over which the airport operator has direct control (sources from scopes 1 and 2), with the possibility of including certain scope 3 sources and other greenhouse gases than CO_2. A list of other sources of emissions (scope 3) is also required.
- Level 2, Reduction: same as the inventory for level 1, and a management plan for carbon emissions produced by scope 1 and 2 sources must be developed and implemented. Evidence to support ongoing measures, reporting and emission reductions must also be provided.
- Level 3, Optimisation: the inventory needs to be expanded to include some scope 3 sources, (at least) taking into account the aircraft LTO cycle, the GAP, surface access and business trips. The carbon emission management plan must be expanded to involve other stakeholders and ongoing emission reductions must be demonstrated.
- Level 3+, Neutrality: same as the requirements for level 3, and the airport operator must demonstrate that they have offset their residual emissions from scopes 1 and 2 and have therefore reached "*carbon neutrality*".

Only the management of CO_2 emissions is mandatory under the ACA programme. The inclusion of other GHG emissions is optional.

TEXT BOX 8

Many airport initiatives are therefore to be highlighted with a view to reducing their emissions. **In October 2018, Côte d'Ivoire's busiest international airport, the Félix Houphouët-Boigny Airport serving Abidjan, renewed its Airport Carbon Accreditation at the highest level (3+ Neutrality). To date, this airport is the only one on the African continent to have reached this level of maturity in carbon management.** In September 2018, the partnership between Brisbane Airport headed by Brisbane Airport Corporation (BAC), Virgin Australia and Australia's leading supplier of transport fuels Caltex resulted in a series of conclusive tests regarding the use of biofuel for flights of the company. Successful testing is an important first step for stakeholders and the Queensland government is ensuring that Australian airports and the fuel supply chain are ready to provide biofuels on a regular basis while developing a genuine local sector. Flight path optimisation and tarmac taxiing on landing and take-off are also part of the solutions to reduce fuel consumption in airports. Air France – KLM, for example, encourages its pilots to use eco-friendly practices by optimising the transport of fuel or by cutting one of the two engines during taxiing.

On the ground, the airline is also using electric track vehicles (50% of the fleet). Objective for the Franco-Dutch group: improve its energy efficiency by 20% by 2020 compared to 2011 levels.

ur le groupe franco-néerlandais: améliorer son efficacité énergétique de 20% d'ici 2020 versus 2011.

CONCLUSION

The extremely fast growth of air transport as envisaged for the coming decades (increase in mass tourism, in particular) places all the players involved (manufacturers, airlines, airports) in the face of a major challenge of controlling carbon emissions. As an exception to the agreements between countries under the umbrella of the Climate Convention, air and maritime transport regulation was left to the responsibility of the players themselves through the intermediary of international organisations (ICAO, IATA), although national governments obviously continue to watch over their interests as we have seen with the European ETS. This system of regulation is also based on a refusal to limit the growth of the sector; it has not yet demonstrated its feasibility, and it raises a lot of scepticism about the two preferred tools – offsetting and the call for biofuels.

However, it should be noted that the players are truly investing in technological developments (engines and fuels) and forming industrial partnerships, both for flights and ground infrastructure. The impact of these new technologies in terms of raw carbon emissions and environmental sustainability (including biofuels consumed) will be a key issue in the coming years.

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