With continuous compound growth of 5% per year, commercial aviation's CO2 emissions will increase by about a factor of five with no improvements to operational efficiency and the adoption of a less polluting fuel. The industry's plan to limit and then reduce emissions is examined.

Commercial aviation's CO2 emissions challenge

Global commercial aviation activities account for 2.0-2.5% of all human production of carbon dioxide (CO2). With the continual annual rise in airline traffic, and therefore aircraft movements, fuel consumption and CO2 emissions will rise by the same proportion. Commercial aviation will therefore account for an increasing portion of human CO2 emissions, unless industry-wide changes are adopted over the next 35 years.

Regional, national and international schemes have been devised to cap and reduce CO2 emissions over the short and medium term. The International Civil Aviation Organisation (ICAO) has set a long-term objective for an ambitious reduction in CO2 emissions by 2050.

The schemes to limit and cap CO2 emissions, and the alternative and replacement fuel technologies that may allow commercial aviation to achieve this long-term reduction are examined.

Global CO2 emissions

It is estimated that in 2015 all human activities produced 36 billion (Bn) tonnes of CO2 *(see table, page 40)*. ICAO estimates that global commercial aviation accounted for 1.7% or 600 million (M) tonnes of this, compared to 25Bn tonnes of CO2 produced by all human activities in 2005, of which 332M tonnes or 1.3% were due to commercial aviation.

Forecasts are that the commercial aviation industry will grow at an average compound rate of 4.9% per year. Without any improvements in technology or operational efficiency, or adoption of a fuel with a lower carbon output, the industry's CO2 emissions will reach 2.7-3.0Bn tonnes by 2050 *(see table, page 40)*. If emissions from the industry reach this level, they will account for 22% of all human-related CO2 emissions.

The Kyoto Protocol is an international agreement, initiated by the United Nations Framework Convention on Climate Change (UNFCCC), which came into effect in 2005. It was signed by all UN members, totalling 192 countries. Its long-term objective was to agree that the increase in average global air temperature as a result of all human-produced CO2 emissions would not exceed 2.0 degrees Centigrade.

Under the Kyoto Protocol signatories were given targets for reduction of CO2 emissions by all their industries and associated human activities, except for international aviation and shipping, which were dealt with separately.

The European Union (EU) devised the Emissions Trading Scheme (ETS) to limit and cap CO2 emissions by all industries and activities in the EU. From 2005, all stationary producers of CO2 emissions had to establish and then set the quantity of CO2 they produced annually. This was extended to aviation emissions in 2010.

The Kyoto Protocol was followed by the Paris Accord in 2015, which also dealt with capping and reducing CO2 emissions by civil aviation separately.

Aviation CO2 emissions

ICAO has set an ambitious target for the global aviation industry of reducing net CO2 emissions to 50% of 2005 levels by 2050. The level of CO2 emissions in 2005 by global commercial aviation was 330M tonnes, so the target for 2050 is 170M tonnes *(see table, page 40)*.

This target must be considered against continued annual growth, which is forecast at an average cumulative rate of 4.9%. ICAO data shows that in 2015 global commercial aviation carried 3.6 billion passengers, generated 817Bn revenue-tonne kilometres (RTKs), consumed 63Bn US Gallons (USG) or 190M tonnes of fuel, and produced an estimated 600M tonnes of CO2 *(see table, page 40)*. Consumption of a tonne of Jet A1 fuel produces 3.16 tonnes of CO2.

With compound annual growth averaging 4.9%, these figures will reach about 19.0Bn passengers and 4,500 Bn RTKs per year by 2050. This is an overall increase by a factor of 5.3. If the industry does not improve operational efficiency, and no new fuels with lower net CO2 or carbon production characteristics are introduced, it is estimated that its CO2 emissions will reach 2.7Bn tonnes per year by 2050 *(see table, page 40)*, on the basis of consuming 852M tonnes of Jet A1 fuel per year. This represents an increase in CO2 emissions by a factor of 5.3 from 2015 levels, and with no gains in operational efficency.

ICAO's target is to reduce net CO2 emissions from global commercial aviation to 170M tonnes per year, or 50% of 2005 levels. This is achievable only through the widescale use of a low net carbon-producing alternative fuel.

The industry therefore has to achieve a reduction of 2.5Bn tonnes of net CO2 emissions per year, equal to 92%. This is the difference between the level of CO2 emissions with no efficiency gains and no new fuels, and the target levels of 170M tonnes.

This reduction of 2.5Bn tonnes is known as the 'emissions gap', and is equal to a reduction in consumption of fuel by 791M tonnes or 263Bn USG. If this is achieved, then commercial aviation's portion of total CO2 emissions will be kept at the 2.5-3.0% level.

CO2 reduction

The UN recognises that commercial aviation is likely to be one of the last industries to find solutions to limit and

GLOBAL COMMERCIAL AVIATION INDUSTRY SIZE & FUEL CONSUMPTION

YEAR	2005	2010	2015	2020 projected	2035 projected	2050 projected
Passengers carried - millions	1,970	2,700	3,500	4,450	9,300	19,300
Revenue Tonne Kilometres - Billions		644	817	1,050	2,200	4,500
Fuel consumed - Billions USG	35	47	63	80	153	284
Fuel consumed - Millions tonnes	105	142	190	239	459	852
CO2 emissions- Millions tonnes	332	449	600	755	1,450	2,700
CO2 emissions due to commercial aviation with no changes to fuel & operating efficiency, and use of alternatives fuels			2.0%			22.0%

reduce its overall CO2 emissions. This is compounded by its average annual growth rate of 5% over the long term. A strategy and objective for reducing CO2 is needed that will not impede the industry's growth as emissions are cut.

The overall objective is for the profile of CO2 emissions from 2005 to 2050 to rise almost in line with continual growth in traffic and the airline fleet, with net emissions peaking in 2035.

Emissions will not rise in proportion with growth in traffic and operations, because modern aircraft are operationally more efficient and have improved fuel burn performance. The long-term objective is for net emissions to decline from 2035 and be at 50% of 2005 levels by 2050. This is only possible if alternative fuels with net carbon emissions lower than Jet A1 are available and used in sufficient quantities.

Three-tier approach

The industry has devised a three-tiered approach to achieving the long-term goal of cutting net carbon emissions to 170Bn tonnes of CO2 by 2050.

The first approach is using more fuel-efficient aircraft and improving airline operational efficiency through to 2050. This will reduce CO2 emissions compared to no action being taken.

The introduction of new and more fuel-efficient aircraft and engines into airlines' fleets, and the phasing-out and retirement of older types is a constant process. The most modern and current types, such as the A320neo and the 737-800, burn 45-50% and 35-40% less fuel than the 1960s vintage equivalent-sized aircraft like the 727-200. This long-term improvement in fuel burn efficiency is expected to continue. The International Air Transport Association (IATA) predicts an average improvement in fuel burn of 1.5% per year over the long term.

While the A320neo, 737 MAX, 787 and A350 are the latest generation of aircraft, two new generations of aircraft and engines may have been introduced by 2050. Future aircraft generations may be powered by engines that use ultra-high-bypass technologies to achieve large improvements in fuel efficency.

Smaller contributions to reduced fuel burn can come from increased use of winglets and other aerodynamic devices. More are likely to be incorporated as standard in the design of new types.

Operational efficiency

Operational efficiency involves adopting techniques that will improve an airline's operation. Those with the largest impact will increase the efficiency of RTK production relative to fuel consumption.

Small and incremental gains in operational efficiency can also be realised through operational techniques, such as weight saving, continuous descent approach, and single engine taxi *(see Systems and techniques to reduce fuel consumption, Aircraft Commerce, December 2015/January 2016, page 27)*.

Another main contribution to reduced fuel consumption per RTK, or per passenger carried, is an increase in passenger load factors. These have already increased by 15 percentage points over the past 20 years, especially since the adoption of new revenue management techniques with regard to passenger spill.

Overall, these operational efficiencies are expected to reduce fuel consumption and CO2 emissions by 5% over the next 35 years compared to no improvements being implemented. ICAO estimates that these techniques will reduce emissions by 700M tonnes per year to 2.0Bn tonnes by 2050, compared to taking no action.

CO2 emissions can be reduced still further with more efficient use of airspace and reduction of flight and block times, achieved by improving air traffic control (ATC) systems, and easing airport congestion. ICAO estimates that this could reduce CO2 emissions by 200M tonnes to 1.8Bn tonnes by 2050, and so the emissions gap down to 1.6Bn tonnes. Improvements in operational efficiency and use of infrastructure would bring the industry's CO2 production down to the same levels by 2040.

Carbon offsetting

The second main tier for closing the emissions gap involves adoption by the industry national, regional or international carbon trading or offsetting systems, such as the EU's ETS. These will mainly reduce the increase in emissions or limit it in the short term, and then limit emissions in the medium term.

By January 2010 when the EU's ETS for aviation came into effect, airlines operating in EU airspace had to record and report their annual CO2 emissions, based on fuel used, and RTKs by the end of March 2011. The first year's data that had to be filed was for 2009. The EU gave its airline industry a free quota of CO2 emissions that was equal to 85% of what the industry had collectively produced in 2009. Each airline's share of this 85% block was based on its share of the industry's total RTKs. The remaining 15% was available to buy via auction.

These two portions capped the industry's CO2 emissions at 2009 levels for 2010 and 2011. The ETS then slightly reduced the industry's total permitted CO2 emissions to 97% of its average of 2004-2006 levels in 2012, and then down to 95% in the 2013-2020 period. This is up to the end of the EU ETS scheme.

The EU's annual airline industry CO2 emissions are expected to be 210-220M tonnes, from an annual fuel consumption of 66-70M tonnes, or 23Bn USGallons (USG), of fuel per year.

The EU ETS therefore acts as a CO2 production quota for the airline industry as a whole, and for each airline. Given

Under the Paris Accord and CORSIA system, the commercial aviation industry will be able to purchase CO2 emissions credits from non-aviation industries. This will be necessary for airlines and commercial aviation to keep CO2 emissions at a constant level from about 2020.

that each airline has a CO2 production volume allowance, it will be incentivised to improve the fuel consumption per RTK generated by using operational techniques and modern aircraft types as described.

The EU ETS also permits airlines to buy further CO2 credits from other industries in the EU. This allows them to increase their CO2 production, which is essential for expanding their operations.

This is only possible if CO2 allowances become available, and this depends on by how much other industries have reduced their emissions. Allowances can be sold via one of several energy exchanges across Europe, or state-run auctions that are held every quarter.

The 2009 price for carbon emission allowances was €14 per tonne of CO2; equal to €44 per tonne or €0.13 per USG of fuel. This acts as a surcharge on the basic fuel cost to operate aircraft above the airline's 100% carbon allowance.

The market rate has dropped in recent years to €5-6 per tonne, because so many CO2 credits are available on the market.

Stationary CO2 emitters, such as industrial entities or power stations, may sell CO2 credits to airlines, but airlines are not permitted to sell credits. A CO2 emitter may also bank the production credits for use in future years when it may need to increase production.

Reducing CO2 emissions for non-aviation industries has been relatively easy. "The problem is that the EU gave out too many CO2 credits to non-aviation industries, so there is a surplus of credits on the market," says Hind. "This has brought the price down to €5-6 per tonne, but it needs to be €30 per tonne for industries to have an incentive to reduce CO2 emissions.

While airlines can reduce aircraft fuel burn by 1-2% through operational techniques, they are likely to save 5-12% in fuel for each aircraft replaced by a new-generation type over the long term. Airlines have only been able to make small or marginal improvements in fuel efficiency per RTK, so they need to acquire carbon credits if they are to meet the annual cumulative traffic growth.

"Under the ETS, airlines could apply for additional free credits in 2011 and 2015," says Guido Harling, chief executive officer and founder of ETSverification. "In all other years they have had to buy credits to satisfy growth requirements. Although global growth is averaging 5% per year, intra-European traffic has seen little growth since the EU ETS came into force. Flights by non-EU carriers to and from the EU are exempt from the EU ETS, so although such traffic growth has been high it has not been fuelled by the purchase of more credits."

In contrast, non-aviation industries have made significant reductions in a relatively short period with techniques and practices that have been relatively easy to adopt. These have yielded carbon allowances or credits that can be bought by airlines through the ETS.

CO2 allowances are traded through dedicated stock exchanges, such as the Energy Exchange in Leipzig, Germany. The price paid depends on supply and demand of carbon credits. Demand from airlines wil be constant each year with continual traffic growth, especially for low-cost carriers (LCCs) that experience higher than average growth rates. Supply will be less reliable, however, and is only available when non-aviation industries consistently reduce their emissions.

A small amount of carbon credits must be bought by airlines to get back to 100% of their 2009 levels, and more are needed for expansion and growth.

As non-aviation industries reach the limit of their ability to reduce CO2 emissions, and some need to buy further credits, the supply of CO2 allowances will diminish, and the price will increase.

The EU ETS is just one example of CO2 capping or limitation schemes under the Kyoto Protocol. Many other parts of the world implemented similar schemes. Australia, New Zealand and several other non-EU states have set reduction targets for CO2 emissions.

The US and China did not ratify the Kyoto Protocol, so they have not implemented CO2 capping and reduction schemes for the short and medium term for their commercial aviation industries.

The targets for CO2 reduction under these schemes have varied. Moreover, under the Kyoto Protocol, most CO2 capping and reduction schemes were national, regional or continental. Few covered emissions for international or inter-continental operations.

CORSIA

The Kyoto Protocol ended in 2012, and was followed by the Paris Accord, which began in 2015, and was signed by 196 countries, about half the world. Of those that did not sign, many are under-developed or third-world countries, with little industry and low CO2 emissions.

The Paris Accord covers most industries and human activities that produce CO2 emissions. The UN gave ICAO responsibility for dealing with CO2 emissions for commercial aviation under the Paris Accord.

There was pressure on ICAO to form a global plan to reduce CO2 emissions as part of the Paris Accord's overall objective to limit the rise in global temperatures to 2.0 degrees Centigrade.

ICAO devised the Carbon Offsetting Reduction Scheme for International Aviation (CORSIA) for global commercial aviation in November 2016 to limit and the cap CO2 emissions for the short and medium term.

The EU ETS, devised under the Kyoto Protocol, continues until 2020. ICAO will start CORSIA as a voluntary scheme for airlines registered in the Paris Accord's signatory states, and will operate from 2021 to 2027. CORSIA will then be mandatory for all airlines in member states from 2027 to 2035.

The EU ETS will therefore take all airlines in EU countries up to the start of CORSIA in 2021, after which CORSIA will be mandatory for all EU airlines.

CORSIA will cover all commercial aviation activities. "The UN will classify each airline into one of three categories, based on the country they operate in," says Harling. "These categories will include a developed industrialised country, and an undeveloped country. North American and European airlines, for example, will go under developed industrialised countries.

"The UN will set up a web portal for each airline to report all of its annual passenger and traffic data, including international operations, and its CO2 emissions data," adds Harling. "Each country's airlines will be assigned a CO2 production quota, as with the EU ETS. The free allowance will be larger for airlines from an underdeveloped country. CORSIA will allow airlines to trade their CO2 allowances with each other. ICAO will also set up workshops to help airlines adopt the CORSIA system."

The UN will also sponsor certified emissions reduction (CER) environmental projects, such as re-forestation, solar energy parks, wind farms, and CO2 capture and storage facilities. As these CERs reduce atmospheric CO2 they will yield an emissions credit that the UN will sell to industry or to airlines to enable the airline industry to grow without raising overall carbon emissions.

"The funds raised from buying these credits finance projects such as the development of biofuels," says Harling.

The long-term objective of CORSIA, and other carbon offsetting programmes, is to reduce CO2 emissions. It is projected that the trading of CO2 credits and allowances with non-aviation industries could maintain commercial aviation's net CO2 emissions at similar levels from 2020. These are projected to reach 755M tonnes, so trading schemes would reduce CO2 by 1Bn.

If this were achieved, then a further reduction of a net 585M tonnes would be required for the industry to meet its target of a net output of 170M tonnes by 2050.

Long-term reduction

For the long term, the aim is to reduce net carbon output through the widespread adoption of biofuel with the same or similar gross CO2 output, but a lower net carbon output compared to Jet A1. It may even have a net CO2 output of zero or close to zero, because a biofuel will absorb atmospheric CO2 during the production of the plant material used to manufacture the fuel.

Without any improvements in operational efficiency, the industry will be producing a minimum 2.7Bn tonnes of CO2 by 2050, from a consumption of 860M tonnes of fuel. This will be reduced to 570M tonnes of fuel through gains in operational efficiency and use of modern aircraft. If carbon offsetting programmes achieve an effective reduction to 755M tonnes of CO2, this will be equal to the industry consuming 240M tonnes of fuel.

The industry consumed 105M tonnes of fuel in 2005, so a reduction of 185M tonnes on consumption of Jet A1/A and replacement by a carbon-neutral alternative fuel would be required.

Alternative fuels

An alternative fuel that is suitable for jet transport aircraft has to meet several criteria. The first is that it must have similar physical properties, such as boiling and freezing temperatures, density and caloric value, to Jet A1/A so as not to impede aircraft operations. It must also have all the physical properties that allow relatively easy certification by regulatory authorities in current technology engines. Some changes to engine design may be needed to certify an alternative fuel.

"A wide range of alternative fuels is

available, but none is certified to be used at a 100% level," says Maarten van Dijk, chief executive officer at SkyNRG, based in the Netherlands. "All alternative fuels must be blended with conventional Jet A1/A, and the highest rate of blend is 50%.

"A fuel must be approved by the ASTM in North America, and tested by the original equipment manufacturers (OEMs) of the engines to determine the maximum level that can be blended with Jet A1/A," adds van Dijk. "It must also be approved to Defence Standard, a procedure in Europe. The two combined levels of approval make the Joint Operations Manual, and the fuel can be used at European airports if approved."

Another major criterion for a suitable alternative fuel is that it must come from a non-food producing crop, to prevent competition from raising the price of the fuel and food. There are also concerns over the limited availability of high quality farmland for food production.

An alternative fuel must also have a cost that is close and comparable to Jet A1/A. Given that 43 USG of Jet A1/A can be produced from a barrel of oil, and that a 'crack spread' cost of $20 per barrel can be added for refining and production costs, then current oil prices of $52-55 per barrel are equal to a spot price of $1.70-1.74 per USG of Jet A1/A.

Jet A1/A at these prices is low enough for most airlines to operate profitably. Indeed, with advances in operational efficiency, most carriers can cope with fuel prices of up to $2.0 per USG.

The industry will only achieve its long-term objective for 2050 if there is an alternative fuel that has all the required physical properties, can be produced in large enough quantities, and be made available at a competitive price.

Alternative fuel characteristics

The aim is to produce an alternative fuel with a lower net carbon output than the conventional petroleum-based fuels, Jet A1/A. The net carbon output depends on two factors: the original feedstock material and the production pathway.

Alternative fuels can be grouped into a few broad categories. The first sub-division is between renewable and non-renewable feedstock material. Fuels made from renewable feedstock sources have a lower net carbon output than fuels made from non-renewable material.

Non-renewable materials that generate alternative jet fuels are coal and gas. Renewable materials include agricultural and non-agricultural crops, sugar crops, cellulosic plants, oleaginous plants, alage, used cooking oils, animal fats, and municipal waste. These make renewable jet fuels (RJFs).

Renewable feedstock materials can be further divided into two groups: all types of plant materials; and three main types of waste materials comprising used cooking oil, animal fats and municipal waste. Fuels derived from plant materials are classed as biofuels.

As well as feedstock material, another issue is the production pathway. There are six main production pathways. The first to consider is the Fischer-Tropsch (F-T) method. "This has two stages, the first of which converts the feedstock material into gas," says van Dijk. "The second stage converts the gas into larger molecules, which results in several fuels, including jet fuel. The F-T process is used to convert coal and gas to liquid jet fuel, but these fuels have a similar carbon output to Jet A1/A."

The F-T process can also convert lignocellulosic biomass and plant material into an RJF. Biofuel produced with this method is the only alternative fuel certified to be used at 100%.

The F-T process can also convert municipal waste, but collecting it is time-consuming and expensive, and leads to emissions being generated. A scheme to produce fuel for BA Cityflyer's operations at London City Airport was abandoned in early 2016 because of the high cost of producing this fuel.

The quantity of renewable and sustainable alternative fuels for commercial aviation is small. Current production levels are in the order of thousands of tonnes. Several companies, including Neste, however, have the production facilities to produce a few millions tonnes per year of green diesel for aviation. This is equal to 1.0-1.5% of the industry's requirements.

"Any fuel generated using the F-T process can be blended at a rate of up to 50% with Jet A1/A," says van Dijk.

A major production pathway for biomass is the production of hydroprocessed esters and fatty acids (HEFA), which is used for oleaginous plants, used cooking oil and waste animal fats. This incurs the expense of collecting small quantities of these materials from a large number of locations, which also leads to high emissions being generated.

"HEFA fuels can be blended at a maximum ratio of 50% with Jet A1/A," says van Maarten.

Cellulosic plants can also be converted to a biofuel RJF by the process of catalytic cracking to generate a hydrotreated depolymerised cellulosic jet (HDCJ) fuel.

There are three main pathways for converting sugar and starch plant materials from cereal crops. The first of these is the alcohol-to-jet (ATJ) process. The second is the aqueous phase reforming (APR) process.

The third process is the direct sugar to hydrocarbons (DSHC) process. It is also referred to as SPK. "This can only be blended with Jet A1/A at a maximum ratio of 10%," says van Maarten.

"The main problem with all of these alternative fuels and RJFs is that they cost at least three times and up to 10 times the cost of Jet A1/A," says Peter Hind, managing director of RDC Aviation. "This is too high, especially when the cost of Jet A1/A accounts for 30% of long-haul operations' cash operating costs.

"A long-term solution may be a fuel derived from algae," continues Hind. "Algae have the advantage of growing fast and in large quantities. Algae farms can be located in industrial locations and brownfield sites. They also use waste water for production, and even clean the water in the process. Most importantly, algae absorb CO2 quickly."

Hind says it will probably be 2040 before algae-based fuel is available on an industry-wide scale to be at a comparable cost to Jet A1/A. "Much more understanding is needed before significant volumes are produced," says Hind. "To achieve such a scale requires a joint international programme, which would lead to standardised algae-based fuel production. One approach is to locate algae farms next to factories, with CO2 emissions being pumped to the algae farm, but this is logistically difficult."

Sierk de Jong, a member of the business development team at SkyNRG says that algae-based fuel is still at an early stage of development. "Making this work will be difficult. Although algae absorbs a lot of CO2 and sunlight, and grows fast, a lot of energy is used to extract the oils, either by compression or by centrifuge. Using current technology and production methods, its overall net carbon output is not much lower than that of Jet A1/A," explains de Jong.

"While the industry has committed itself to carbon-neutral growth from about 2020, it is unlikely to achieve this," says Hind. "The solution from 2020 for another 10 years can only be achieved by the industry acquiring carbon allowances and credits from non-aviation industries, since RJFs are unlikely to be available in sufficient quantities to assist this process.

To make the leap from small research projects to large-scale production a structural financing mechanism is needed.

"The combined output of all alternative fuel programmes is very low," says van Dijk. "Production from all jet biofuel programmes totalled 100 tonnes in 2015, only enough to fuel a 747 for a single long-haul operation. Volumes in increased in 2016 to 2,000 tonnes, but only enough for some corporate jets and general aviation operations. Production is forecast to triple in 2017, but this is nowhere near the industry's annual consumption of more than 200M tonnes.

"The problem is the supply chain, and the limited number of significant production units," continues van Dijk. "AltAir Fuels, which is based in Los Angeles, California, is the only large production unit of biofuel. It produces a green diesel for aviation from waste oil using the HEFA process."

There is a big development of several facilities globally owned by Neste, and based in the Netherlands, Singapore and Finland. Other companies produce a similar fuel and have facilities in China and the USA.

These produce a diesel from waste oil using the HEFA process or road vehicles. Neste and Boeing use existing facilities to produce a 'Green diesel' for jet fuel. SkyNRG organises the logistics for delivering the fuel to airports. "Neste is expected to make 3.5M tonnes of HEFA fuel per year for commercial aircraft," says van Maarten. "The aim is for it to be certified for blending with Jet A1/A at a rate of 10-20%."

The production volume will be 1.0-1.5% of the industry's needs, and there are not enough waste oils to supply the entire aviation industry. The fuel costs two to three times more than Jet A1/A, so it is cheaper than HEFA fuels made from other feedstock materials, and the price should fall as production volumes rise. The net carbon production of this fuel should be 50-60% of that of Jet A1/A."

Giving moral support to alternative and sustainable fuels is the sustainable aviation fuel users group (SAFUG). This is a group of airlines that are committed to using sustainable fuels as they become available in sufficient quantities. SAFUG includes Air China, Air France, Air New Zealand, British Airways, Cathay Pacific, Etihad, jetBlue, KLM, Lufthansa, Qantas, Qatar Airways, Singapore Airlines, and United Airlines. - *CHW* AC