The rate of progress of new & alternative fuel programmes has been relatively slow. A faster rate of development is needed to meet IATA's goal of achieving a carbon-neutral fleet and capacity growth by 2020. The progress of alternative fuel programmes is examined.

Alternative & new fuel programmes

Since industrialisation, economic growth has lead to increased production of carbon dioxide (CO2) and other greenhouse gases (GHG). Their increased concentration in the atmosphere has led to a general scientific consensus that we face dramatic climate change and global warming with broad impacts on the earth's ecosystems. The aviation industry's goal is now to stabilise or even reduce the atmospheric concentration of CO2 and other GHG by adopting new fuels.

Commercial aviation now accounts for about 2% of global GHG emissions, despite a remarkable history of engine, aircraft design and fuel-efficiency improvements. The positive effects of these achievements are likely to be far outweighed, however, by the increasing demand for global air traffic, and the continual growth of the global jet fleet.

It is estimated that based on these developments, demand for air travel will grow by 5–6% per year. This is a three- to four-fold increase by 2035. Without extraordinary additional measures, the global airline sector will significantly increase its carbon emissions from 1.5 giga tons (GT) of CO2 (2005) to 2.9GT of CO2 by 2035. The International Air Transport Association (IATA) states that for every kilogram (kg) of fuel saved, the amount of CO2 released into the atmosphere is reduced by 3.16kg (6.97lbs). There is therefore a large incentive for the industry to cut emissions of carbon gases.

Biojet Corporation, IATA's alternative fuels strategic partner, estimates the airline industry's annual consumption at 84 million US Gallons (USG) of fuel.

Based on the growth projections for global aviation traffic, combined with public pressure for a move towards a more sustainable air traffic system, IATA has defined ambitious targets for the industry as follows:

- A +1.5% per annum average efficiency improvement until 2020.
- Carbon-neutral fleet and capacity growth from 2020. This means that CO2 emissions cannot increase from this date, despite further fleet growth.
- An absolute reduction of 50% of emissions by 2050, compared with 2005 levels.

It is already understood by the industry that meeting these targets of 'carbon neutral growth' and closing the gap represents a major challenge. This can only be achieved with a 'thinking-outside-the-box' industry approach and by making significant investments into several new technologies and measures.

New aircraft & engines

New designs in airframe and engine technology are reducing fuel consumption. The new 787 has been designed to emit 15% less CO2 than current aircraft. It entered service in 2011, and according to launch customer ANA surpassed this target to a 20% lower fuel burn.

Jet aircraft's fuel efficiency, in terms of CO2 emissions per passenger-mile, is estimated to have improved by more than 60% over the past 40 years (IPCC 1999). This is due mainly to technological developments such as: as turbojet to first-generation turbofan engines, like the 707/727 and 747-100 aircraft; and first- to second-generation turbofans, such as those on the 777 aircraft.

Third generation engines have designs that provide a further reduction in CO2 emissions. Pratt and Whitney (PW) has developed the GTF engine, which uses an internal gearbox connected to the fan. This reduces fuel consumption, and therefore CO2 emissions, by 12-15% compared to alternative engines.

CFMI has launched the LEAP range of engines offering similar levels of performance and CO2 reductions.

Some efficiency gains have also come through improved airframe aerodynamics and material changes that have reduced weight. In the near term, it is envisaged that most further improvements will be due to increased use of lightweight materials, such as composite fan blades and fan casings, which Rolls-Royce predicts should yield weight savings of up to 1,500lb per engine.

Improved air traffic control

NextGen in the US and Single European Sky Air traffic management Research (SESAR) in Europe are programmes to increase the efficiency of airspace utilisation.

The Single European Sky (SES) is an ambitious initiative launched by the European Commission (EC) in 2004 to reform the architecture of European air traffic management. It proposes a legislative approach to meet future capacity and safety needs at a European, rather than a local, level.

European air traffic management is extremely complicated, because Europe does not have a single air traffic management framework. Air navigation is therefore managed at a country, not European, level. Europe also has some of the busiest skies in the world with as many as 33,000 flights a day.

The European Union (EU) SES legislature was drawn to overcome the fragmentation of air control management and limitations in flight capacity, by structuring airspace and air navigation services at a pan-European level. To develop the needed technological capacity, the SESAR programme was initiated in 2004 as a continuation of Eurocontrol's smaller SESAME-project.

In June 2010, the European and US

IATA has defined ambitious targets for the industry to achieve a carbon-neutral fleet and capacity growth by 2020, and an absolute reduction in carbon emissions by 2050 compared to 2005.

authorities reached a preliminary agreement on inter-operability between their future air traffic management systems, SESAR and NextGen. SESAR's development stage has now ended, and deployment of the infrastructure is expected to be completed by 2020. It is unlikely, however, that any reduction in fuel consumption reduction will be attributed to SESAR until the middle of the next decade.

Accelerated fleet renewal

Fleet renewal has not been economically feasible for many airlines, which have been operating older generation aircraft for a long time.

A recent study showed that airlines that own, rather than lease, their aircraft, are reluctant to replace them, despite the fuel efficiency penalties, potential lack of passenger comfort and amenities, and increasing maintenance costs.

Using older aircraft has its benefits, even if airlines incur higher fuel costs. An airline like Allegiant acquires used aircraft at low values, instead of paying up to $40 million for each new aircraft, which incurs higher financing costs, and leaves the airline with limited financial flexibility.

Southwest Airlines, which in the past always acquired its aircraft from new, has bought used aircraft from WestJet. Southwest chief executive officer Gary Kelly announced this move in May 2013, hoping to cut capital spending through to 2018 by $500 million, by delaying deliveries of 30 new 737s. Kelly said that Southwest can buy very good aircraft, with 10-15 years' life remaining. This bold move could leave the airline exposed if fuel prices rise dramatically.

Due to a long replacement cycle, many of the aircraft in service now will still be in operation beyond 2020.

Future technology improvements, however, are foreseeable. The further development of alternative energy sources, such as aviation biofuels, seems to be the only known means of closing the growth in the 'carbon-neutral' gap. Carbon-neutral describes fuels that neither contribute to, nor reduce, carbon emissions. The carbon-neutral gap is the difference between actual industry emissions, and IATA's emissions targets. This will continue to increase as the fleet grows, and conventional fuel continues to be used.

In that respect, the airline sector specifically differs from ground transport, which has several emissions reduction options from alternative energy sources other than biofuels, such as fuel cells and electrically powered trains.

The aviation sector therefore has a special demand for drop-in fuels to replace kerosene. It is easier and cheaper for biofuels to be used in the ground transport sector.

Alternative fuels

The exploration and development of sustainable, next-generation aviation biofuels is a major challenge. The technical specifications of jet A1-kerosene are very demanding. Kerosene jet A-1 has to work between -40°C and about 45°C. These temperatures reflect the wide range of conditions that commercial aircraft operate in.

Traditional biofuels, for example, have yet to fully work at temperatures below -30°C. Aviation biofuels can only meet this technical specification through more advanced manufacturing processes.

These require higher investments than those for other types of biofuels, such as ethanol or fatty acid methyl esters, which can be used for ground transport.

Manufacturer tests of next-generation biofuels, such as those based on jatropha plants, have, however, raised the hope that their comparable energy density to kerosene means that no significant aircraft engine modification will be needed, and drop-in fuels could become a reality.

An estimated $2–3 billion investment will be needed to provide sufficient aviation biofuels feedstock supplies, and to build up production facilities and new global supply chains to deliver aviation biofuels at the required global demand. Global demand is estimated to be at least 50 million tons by 2020, assuming a global kerosene drop-in rate of 10%.

Current extraction and production costs of aviation biofuels are still four to seven times higher than those of conventional jet fuel. For aviation biofuels to become competitive and to be widely adopted by the industry, a substantial cost reduction is therefore required (within the physical and calorific specifications that the new fuel has to meet) to make the economics work. As such, many questions on 'how to get there' are unresolved on a technical, commercial and regulatory level. Small steps, however, are being taken in the right direction that could lead to large-scale increases if the production methods can be rolled out more widely.

Promising next-generation biofuels, such as Fischer–Tropsch (FT) jet fuel produced from wastes and/or specially grown lignocellulosic biomass, are becoming available in sufficient quantities. Currently known biofuel technologies based on sugar or starch fermentation, or vegetable oil hydrogenation, are being further developed as drop-in jet fuels.

British Airways (BA) announced in mid-April 2014 that it would be buying all of the biofuel made at the GreenSky London facility in Thurrock, Essex, UK. The facility is owned by Solena, and will use the Fischer-Tropsch (FT) technology provided by the partner Velocys to convert waste otherwise destined for landfill into low carbon jet fuel and biodiesel. GreenSky has acquired the site,

Fleet growth, and the continued use of conventional fuel, means that the gap between actual carbon emissions and the target of a carbon-neutral industry is widening rather than narrowing.

which is the former Cortyon Oil Refinery. A large portion of the infrastructure required to process the waste into fuel is therefore already in place.

Solena Fuels will use a combination of two technologies to make the fuel. Once the waste has been cleaned of any hazardous or recyclable materials, it will be combusted in a low-oxygen environment that produces a synthesis gas of hydrogen and carbon monoxide, a process known as gasification. The gas will be converted to liquid fuel, using the FT process, with a 5,000 deg C plasma gasification system required over and above the traditional processing plant and gas recovery systems. This is not new territory for BA, which has long purchased its jet fuel from the South African energy company Sasol that uses the FT process to convert coal into a drop-in fuel in a blended mix.

Biofuels are becoming more economically viable, due to research, and the maturity of processing methods and costs. The main setback is that the airline industry is not yet willing or able to pay price premiums for them, given their small profit margins. The use of, and investments into, aviation biofuels are being promoted in the context of new carbon policy measures, such as emissions trading and potential carbon tax schemes.

Moreover, the impact of converting BA's flights to the use of these fuels would be minuscule. Fuelling BA's London-New York services with biofuel would displace just 2% of BA's consumption of conventional fuel at its London Heathrow hub. BA expects to increase gradually its use of the new fuel, in compliance with a UK aviation industry road map, which sets the goal of obtaining 30% of fuels from renewable sources by 2050.

Solena hopes that, by keeping the project small, it will reduce the risk. This aspect helps to attract project funding, since investors are still wary of putting large amounts of money into this area of development because of the inherent risks. It is hoped that this project will serve as a prototype for similar projects around the world, where refuse disposal is becoming a growing problem.

Replacing jet fuel

Commercial and household solid waste represents a promising alternative fuel pathway for the industry. One major advantage is that the feedstock can be sourced and produced near airports, mitigating transportation and logistics costs.

In 2010, a number of US airlines signed a letter of intent to work with Solena on developing fuel from waste. These airlines are likely to revisit that opportunity once the BA project gets off the ground. In the meantime, the US aviation industry is working with the Connecticut Center for Advanced Technology, through a grant from the Department of Agriculture, to foster the development of a fuel made from municipal solid waste.

Airlines are also testing fuels from other feedstocks. Lufthansa, which in 2011 became the first airline to use biofuels in commercial flights, announced in April 2014 that it is researching a new type of biofuel made from fermented plant waste by the US-based company Gevo. Gevo produces alcohol-to-jet (ATJ) fuel blended with conventional jet fuel. Fermented waste from plants is processed to produce isobutanol, a form of alcohol that, when processed conventionally, produces aircraft-grade kerosene.

Airlines are putting alternative fuels into action, too. United Airlines, for example, has an agreement with AltAir Fuels to run flights out of Los Angeles later this year on a commercial scale. This will use renewable jet fuel made from agricultural waste and non-edible natural oil products. Alaska Airlines also has a purchase agreement in place with Hawaii Bioenergy to fly on a sustainable jet fuel made from woody biomass on flights starting in 2018.

Sustainability

To some extent aviation biofuels, taking into consideration their entire supply chain from feedstock cultivation to distribution, are unlikely to become more sustainable than fossil fuels. This is particularly when the effects of direct and/or indirect land use for the cultivation of feedstock, given the volumes required, are taken into account. In that sense, the cultivation of sustainable feedstock has to take a holistic view of global agriculture, and take into account its impact on food production and/or deforestation.

The 'Farm-to-fly' initiative

In July 2010 the US Department of Agriculture (USDA), Airlines for America Inc (A4A), and Boeing signed a resolution formalising their commitment to work together on the 'Farm-to-Fly' initiative. The main goal of this is to "accelerate the availability of a commercially viable and sustainable biofuel industry in the USA".

Farm-to-Fly's aspirational goal is to produce one billion gallons of sustainable alternative jet fuel. This will account for about 6% of the industry's future annual fuel consumption by 2018. Reaching that goal is a stretch, but not impossible, should fuel supplies substantially increase and the price drop through research and process improvements like the GreenSky initiative.

"Airlines are focused on alternative fuels for two reasons," says Nancy Young, vice president of environmental affairs at the trade group Airlines for America. "One is to provide a competitor

To date, only a small number of alternative fuel programmes have been adopted commercially. These account for a small percentage of fuel provided at a small number of airports.

to petroleum-based fuels for reasons of supply and price volatility. Another is the sustainability and emissions goals that we have. Providing some amount of sustainable alternative aviation fuel is very important in meeting those."

The global aviation sector currently accounts for 2% of global emissions, but its carbon footprint is expanding quickly as demand for air travel increases.

Challenges

There are challenges to meeting carbon-neutral growth and fuel efficiency targets by 2020.

There are a large number of issues regarding the widespread use of biofuels, starting with the publicised food-versus-fuel debate. As fuel prices rise, world food prices will also probably increase, due to fixed land availability.

Certain first-generation biofuel crops grown for the production of ethanol, such as corn and wheat, are being diverted from the food market. Other food crops are being displaced in favour of crops for fuel. Some land is also being used for alternative energy production, such as solar panels and wind turbines.

First-generation biofuels are made from sugar, starch, vegetable oil, or animal fats using conventional technology. These are generally produced from grains high in sugar or starch fermented into bioethanol; or seeds that are pressed into vegetable oil used in biodiesel. Common first-generation biofuels include vegetable oils, biodiesel, bioalcohols, biogas, solid biofuels and syngas.

In contrast, second- and third-generation biofuels do not impact on food production.

Research is taking place into developing second-, third- and fourth-generation bioenergy sources that give higher yields of fuel per acre or hectare than first-generation crops. It is difficult to calculate exactly how much fuel a particular area of land can reliably produce. Yields vary with location, and depend on soil nutrient content, the maturity of the crops and on the methods of energy extraction.

Second-generation biofuels are produced from non-food crops, including materials such as cellulosic biofuels and waste biomass (stalks of wheat and corn, and wood). Common second-generation biofuels include vegetable oils, biodiesel, bioalcohols, biogas, solid biofuels, and syngas. Research continues on second-generation biofuels, including biohydrogen, biomethanol, DMF, Bio-DME, Fischer-Tropsch, biohydrogen, mixed alcohols and wood alcohol-derived kerosene.

Third-generation biofuels are produced by extracting oil from algae, sometimes referred to as 'oilgae'. Its production is supposed to be low-cost and high-yielding. It can potentially give up to nearly 30 times the energy per unit of land area as can be realised from current, conventional 'first-generation' biofuel feedstocks. This, however, is yet to be proven on a practical and industrial scale.

Another issue regarding biofuels is the amount of land area required. For biofuels to make a substantial impact, sufficiently large areas of land need to be used for the growth of bioenergy crops.

Although biofuel crops absorb carbon dioxide during growth, about the same amount of carbon dioxide is released when the fuel is burned. These biofuels are therefore close to being carbon-neutral.

The amount of CO2 released when burning a gallon of bio-kerosene, is similar to the amount of CO2 that was absorbed by the plants that produced the fuel during their growth.

The real advantage, as regards carbon abatement, comes from the displacement of fossil fuels. Whether biofuels are actually achieve a reduction in carbon dioxide emissions depends on their method of production. If large areas need to be deforested to clear land for the growth of biofuels crops, or if more energy is being used to grow the crops and to produce and then extract the fuel than obtained from the crop, then the biofuels are not achieving the required reduction in emissions.

The whole life-cycle of a biofuel needs to be considered. Conventional fuels typically contain hydrocarbons. Biofuels contain hydrocarbons as well as sulphur and nitrogen. As a result, biofuels also produce other emissions, such as nitrous oxide and sulphur dioxide. This poses further complex challenges, because nitrous oxide is believed to have a more detrimental effect on the atmosphere than carbon dioxide. This is further reason to perform full life-cycle analyses.

Another pressing issue regarding biofuels is the amount of energy required to grow the crops and to derive the fuels. The energy used to plant and harvest the crops, to irrigate the land and to derive the fuels can be, particularly with first-generation biofuels, considerably larger than the amount of energy obtained from the crops. Much of this required energy is from fossil fuels. With improved methods of energy extraction from the crops, second-, third- and fourth-generation biofuels may consume less energy in their production.

As with all developing technologies, there are considerable costs associated with biofuels. Their future depends on significant investment of time and resources. Camelina, jatropha and algae are all in different stages of development and it remains to be seen what actual yields can be extracted from the waste-derived FT process, or if these plants and crops show potential. Challenges will be presented when moving the processes to a widespread commercial scale. AC