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INTERNATIONAL CIVIL AVIATION ORGANIZATION

Aviation and the Environment

A Global and Effective MBM Roadmap

- Secretariat Perspective on Aviation and Climate Financing
- IATA: Toward a Fairer Outcome for Aviation and the Environment
- Profiling New Zealand's Carbon Trading Scheme

Sustainable Aviation Alternative Fuels: SWAFEA and ABRABA updates

Atmospheric Data Collaboration: ICAO and the WMO

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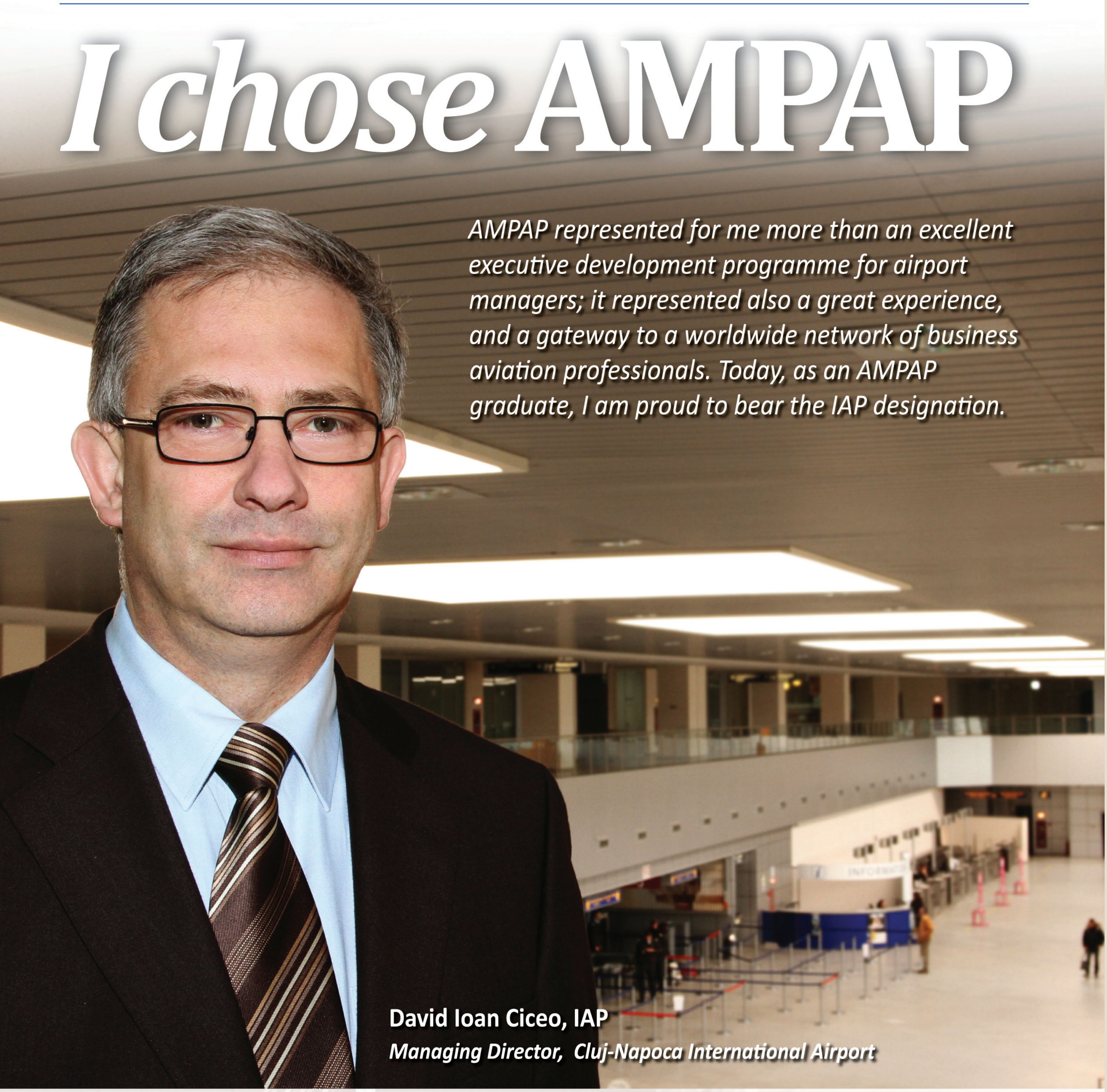

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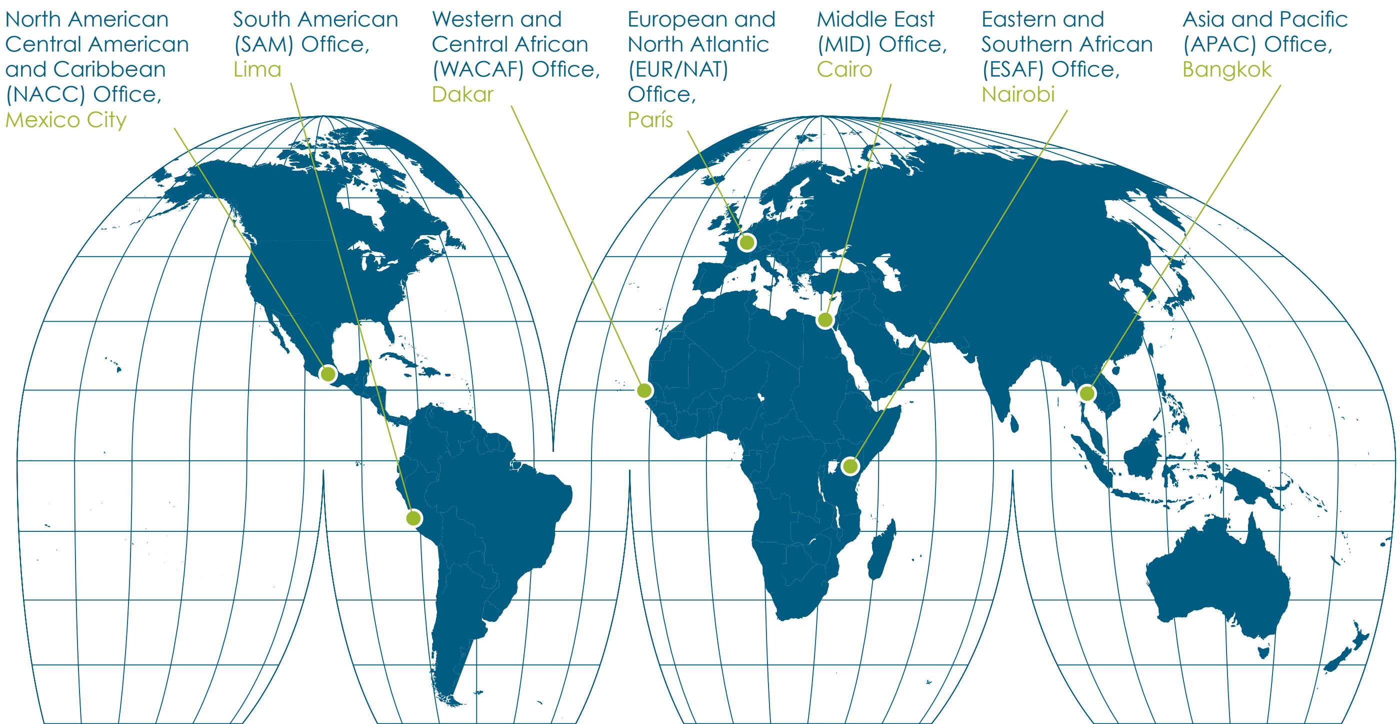

Entering an Action-based Phase in Aviation's Drive to Sustainability

The environmental sustainability of international air transport is one of ICAO's main challenges. Demand for air traffic is projected to grow substantially in the foreseeable future and the environmental consequences of this rate of growth are increasingly called into question. To fulfil its role as a catalyst for economic, social and cultural development, future air transport needs to be sustainable. We are living in a very exciting time as the Organization develops a solid foundation to realize this goal.

The global agreement on aviation and climate change reached at the 37th Assembly was an important step towards this sustainable future and makes international aviation the first sector with a shared global commitment to the environmental goals of increasing fuel efficiency and stabilizing CO_2 emissions in the medium-term. It provides a concrete framework for ICAO and its Member States, in collaboration with the air transport industry, to continue to identify and pursue global solutions to address Green House Gas (GHG) emissions from international aviation.

ICAO is taking the necessary actions to facilitate further progress towards this objective and, in addition to its technical and operational work, is focusing on four strategic building blocks:

1) States' action plans and assistance to States.
2) Sustainable alternative fuels for aviation.
3) Market-based Measures (MBMs).
4) Global aspirational goals.

The agreement on the voluntary submission of **States' action plans** to reduce emissions from international aviation to ICAO has led to a dynamic shift in the Organization's policy outlook on the environment—from a 'Standard policy setting' phase to a more action-oriented 'implementation' mode. The action plans will permit States to identify their basket of measures and assistance needs and allow ICAO to both assess the progress in achieving the global aspirational goals adopted by the Assembly, as well as address the specific **assistance needs of States**.

The Assembly invited States to submit their action plans to ICAO by June 2012. This very tight deadline requires an unprecedented level of effort in the preparation and dissemination of information to States. A more pro-active approach with our Member States was therefore envisaged. Since the Assembly, initial guidance material and a web-based interface have been developed and we are in the process of holding a series of regional workshops to assist focal points nominated by States in the submission of their plans. A brief review of the first of these workshops can be found on page 20.

Concurrent with these actions, the Organization is further exploring a more aggressive assistance policy in this area through its Technical Co-operation Bureau (TCB), in conjunction with the Environment Branch, to better support States as they prepare and eventually implement their action plans.

ICAO is at the forefront of international efforts to facilitate the development and deployment of **sustainable alternative fuels for aviation** on a global scale. These fuels are a key component of the basket of measures from which States can choose to achieve their collective global goal and can be the ‘game changer’ in reaching global aviation emissions goals. ICAO is currently working to support activities that will enable these fuels to be available in a timely manner and in sufficient quantities for use in aviation. The Organization maintains an online global platform that showcases all major developments in this area: the Global Framework on Aviation and Alternative Fuels (GFAAF). A workshop on this topic will be held this October in Montreal.

Although there is general agreement among States that **MBMs** can be a cost-effective approach to address aviation emissions, countries have expressed divergent opinions on the implementation of such measures and much effort will be needed to bridge these gaps. Many initiatives in this area from individual States or groups of countries have recently been implemented or are under consideration.

It is paramount that a patchwork of uncoordinated measures, which could hinder the efficiency of air transport, be avoided.

The Assembly agreed on the guiding principles for MBMs, deciding to explore a global scheme for international aviation. ICAO is coordinating technical studies which will serve as the basis for further policy discussions by the ICAO Council and other fora.

The 37th Assembly agreed to review the medium-term **global aspirational** goal which it had adopted and to explore a long-term goal for international aviation. With the improved ICAO fuel burn data collection system, the ICAO Carbon Emissions Calculator, the forthcoming ICAO Fuel Savings Estimation Tool (IFSET) and the modelling efforts of ICAO’s Committee on Aviation Environmental Protection (CAEP), we are building a solid basis of reliable data from which informed decisions can be made. ICAO is also exploring data-sharing partnerships with aircraft operators and reservation systems.

Another major effort currently underway is the work under the CAEP on the development of a new CO_2 Standard, aiming for completion by 2013.

The ENV-related outreach activities of the Organization continue to be expanded. Our goal is to ensure that ICAO cooperates with the main entities active in areas of relevance and that the public is better informed of the various initiatives being undertaken. To that end ICAO’s 2010 Environmental Report, which is fully dedicated to aviation and climate change, as well as an ICAO video on the same topic, have been widely promoted.

ICAO regularly provides other UN bodies with international aviation’s positions and perspectives on the environment. In particular, ICAO is closely monitoring the UNFCCC’s work on long-term climate financing to ensure that international aviation is not disproportionately singled out as a source of revenue *(see the comprehensive feature story on this topic on page 6)*. The Organization is looking to the UNFCCC to deliver an agreement that acknowledges ICAO’s progress and encourages its Member States to continue to work through the Organization towards the sustainable future of international aviation.

Alongside the United Nations Conference on Sustainable Development (UN CSD), ICAO is in full swing with its preparations for the RIO+20 Conference in June 2012, with a view to providing well-informed insights on the greening of aviation towards a sustainable future.

As we transition to a greener economy, we will have to reassess the way we do business in aviation in light of potential trade risks (protectionism, conditionality, subsidies) and opportunities. Forces driving the transition to a green economy which are relevant to international aviation include environmentally-driven consumer pressures from major customers, as well as the growth of unilateral environmental regulations, rules and policy measures.

Adaptation is also a critical component of a sustainable strategy for international air transport. As much is underway to minimize the effects of aviation on climate change, we are also responding to the Assembly request to look into the potential of climate change on international aviation and related infrastructure. To do so, ICAO is liaising with many international Organizations and UN bodies, such as the World Meteorological Organization (WMO—*see article on page 32*).

Climate change has also presented air transport with a unique opportunity to contribute to the understanding and development of sound solutions to address climate change, derived through data collection by in-situ aircraft high in the atmosphere. Imagine the potential of thousands of flying laboratories collecting data throughout the world, in real time on an ongoing basis. ICAO and the WMO are now combining their efforts to develop the policy framework that will make this vision a reality. This outcome would bestow a new positive and pivotal role for aviation in combating climate change.

Innovative thinking and cooperation have always been key to overcoming aviation’s biggest challenges and it will be no different as we tackle the serious environmental issues now before us. International aviation would do well to build upon the positive, sustainable vision of progress established by the last Assembly. The Organization is committed now more than ever, to leading the development of a solid basis for this greener future. ■

Leadership and Vision in Global Civil Aviation

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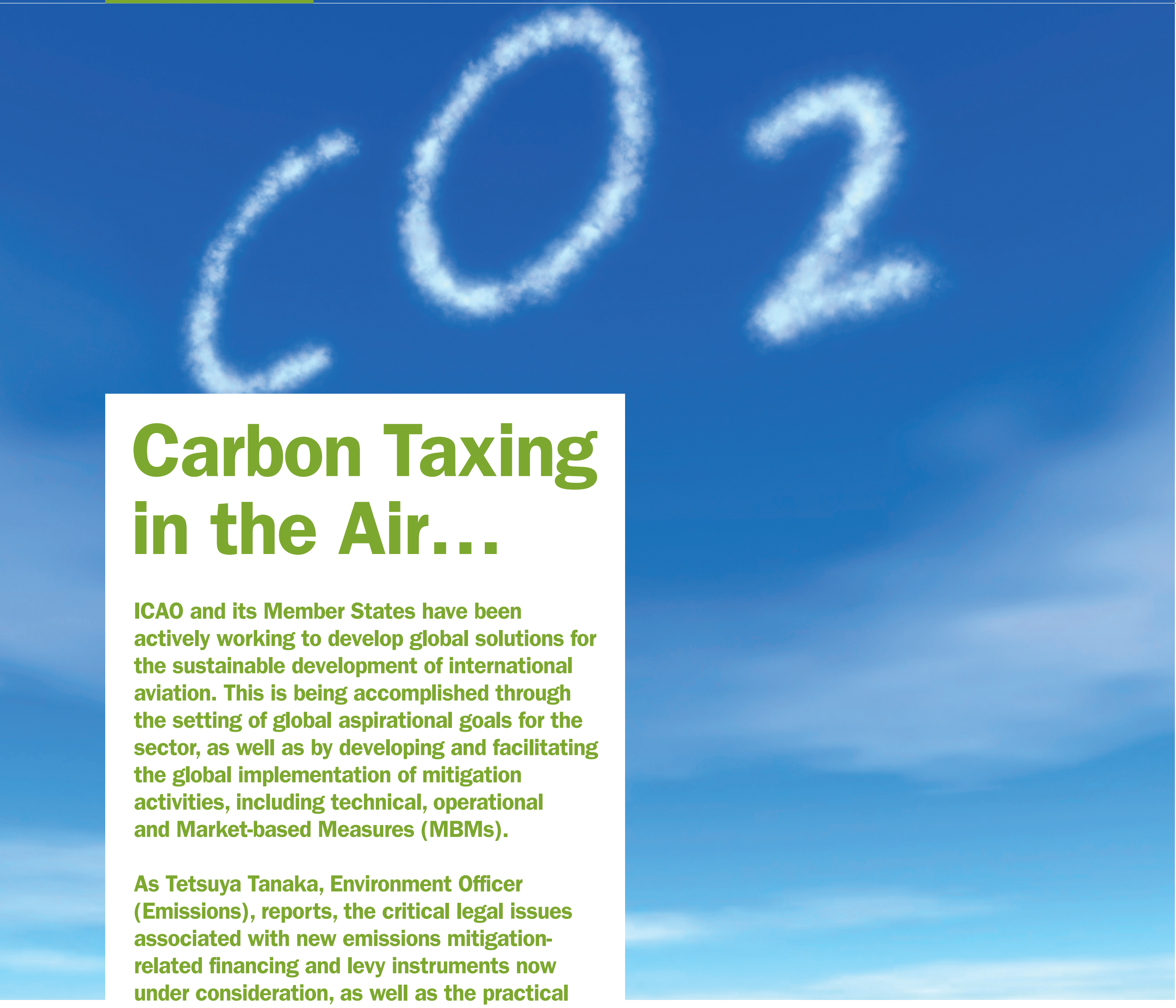


Carbon Taxing in the Air…

ICAO and its Member States have been actively working to develop global solutions for the sustainable development of international aviation. This is being accomplished through the setting of global aspirational goals for the sector, as well as by developing and facilitating the global implementation of mitigation activities, including technical, operational and Market-based Measures (MBMs).

As Tetsuya Tanaka, Environment Officer (Emissions), reports, the critical legal issues associated with new emissions mitigation-related financing and levy instruments now under consideration, as well as the practical challenges arising from the global nature of international aviation emissions, still require further consideration. ICAO has provided leadership in this regard through the guiding principles set out in the Annex to Assembly Resolution A37-19, stressing that any air transport-related MBMs must be applied fairly with respect to other transport sectors and any revenues generated by these MBMs must be used primarily to address aviation-specific emissions.

Tetsuya Tanaka is Environment Officer (Emissions) in the Environment Branch of ICAO's Air Transport Bureau. He provides policy input related to aviation emissions-related matters, in particular the issue of international aviation and climate change, and also supports the activities related to ICAO's cooperation with other UN bodies such as the UNFCCC and IMO. Before joining the ICAO Secretariat in 2008, Tanaka worked for the Civil Aviation Authority of Japan and dealt with a variety of aviation issues, including the environment, airworthiness and bilateral air service agreements.

The climate change Resolution adopted by the 37th Session of the ICAO Assembly in October 2010 reflects the willingness of ICAO's Member States to take concrete steps to develop global solutions to limit or reduce CO_2 emissions from international aviation, thus contributing to the global efforts addressing climate change.

While ICAO presented its developments as an input for the global climate change agreement being negotiated under the United Nations Framework Convention on Climate Change (UNFCCC) process, no specific decision on this subject has been taken under this process given some divergent views that have been expressed by Parties—mainly due to the international aviation sector's mobile and global nature. A similar dynamic was also evident at the recent UNFCCC Conference in Cancun, Mexico, in December 2010 (COP/16).

On a larger scale, the UN Climate Conference in Cancun agreed to limit the global temperature increase to 2°C or lower. This stabilization pathway will require substantial international efforts and significant financing. In this regard one of the milestones reached at Cancun is related to long-term financing—the establishment of a special Green Climate Fund (GCF) designed by a Transitional Committee (TC) which will take into account the report of the High-level Advisory Group on Climate Change Financing (AGF) released in November 2010. One of the options presented in the AGF report relates to the potential generation of revenue through the application of Market-based Measures (MBMs) on international aviation.

Climate Financing under the UNFCCC and AGF Report

UNFCCC COP/16 recognized that developed countries are committed to a goal of jointly mobilizing $100 billion per year by 2020 to address the needs of developing countries. It further agreed that funds provided to developing countries may come from a wide variety of sources, public and private, bilateral and multilateral, including *"alternative sources."*

While COP/16 did not specify the sources of revenue for the long-term climate financing, it took note of the AGF report which will be considered by the TC with respect to the design of the GCF. The outcome of the TC will be reported to the next UNFCCC Conference in Durban, South Africa, from 28 November to 9 December 2011 (COP/17).

The AGF was established by UN Secretary General Ban Ki-moon in February 2009. It was co-chaired by the Prime Ministers of Norway and Ethiopia and its membership included senior ministers and officials from central banks and other experts on finance and development. The Group conducted a study on the identification of practical proposals relating to the significant scaling-up of long-term public and private financing for climate change mitigation and adaptation strategies in developing countries, and how best to deliver it, in the spirit of the political commitments contained in the COP/15 Copenhagen Accord. The AGF report, issued in November 2010 just prior to COP/16 in Cancun, suggested that international aviation could be a potential source of revenue through a fuel levy, passenger ticket tax or emissions trading system, contributing up to $3 billion per year to long-term climate financing *(see information box, below)*. The full text of AGF report is available at:

www.un.org/wcm/content/site/climatechange/pages/financeadvisorygroup

The AGF report may possibly have political, legal and other practical implications for ICAO's existing policies and practices, including Resolution A37-19 adopted by the 37th ICAO Assembly.

Risk of Undermining ICAO's Mitigation Efforts

ICAO and its Member States have been actively working to develop global solutions for the sustainable development of international aviation. This is being accomplished through the setting of global aspirational goals for the sector, as well as by developing and facilitating the global implementation of mitigation activities, including technical, operational and market-based measures. Resources to facilitate the implementation of these measures in all ICAO States and regions, in close

REPORT OF THE UN-SG'S HIGH-LEVEL ADVISORY GROUP ON CLIMATE CHANGE FINANCING (AGF)—NOVEMBER 2010

- AGF concluded it is *"challenging but feasible"* to meet the goal of mobilizing $100 billion per year by 2020 for actions for developing countries, and that *"funds will need to come from a wide variety of sources"*, including:
  - **International Aviation—$2–3 billion per year**
    - 800 MT-CO_2 estimated from global aviation in 2020.
    - 550 MT-CO_2 excluded for domestic/developing countries' flights.
    - 250 MT-CO_2 taxed with assumed carbon price of $25/t-$CO_2$ ($6 billion).
    - 25-to-50 percent of the $6 billion earmarked for climate finance ($2-3 billion).
  - **International shipping—$4–9 billion per year**
  - **International Transport—$10 billion per year**
- AGF recommended that further work on instruments should be undertaken by ICAO and the IMO.

cooperation with the aviation industry, are critical to the achievement of the global aspirational goals.

For example, the world's airlines will need to purchase approximately 12,000 new aircraft at an estimated cost of $1.3 trillion by 2020. Sustainable alternative fuels for aviation offer one of the most exciting and promising opportunities for reducing aviation's GHG emissions and ICAO is now facilitating the regulatory and financial frameworks to ensure that such fuels are available in a timely manner and in sufficient quantities for use in aviation[1].

If the international aviation sector is singled out as the sole source of revenue, this is likely to result in a shortage of resources to facilitate mitigation activities by the international aviation sector itself, and in a disproportionate contribution of resources as compared to other economic sectors. Of note in this regard is that CO_2 emissions from aviation (domestic and international operations) currently account for approximately two percent of total global CO_2 emissions. More than half of aviation's two percent contribution derives specifically from international aircraft movements (roughly 1.2 percent).

The 37th Assembly agreed on the guiding principles for the design and implementation of MBMs for international aviation in the Annex to Resolution A37-19. One of these principles stresses that *"market-based measures should ensure the fair treatment of the international aviation sector in relation to other sectors."* The Assembly also *"strongly recommended that, where revenues are generated from market-based measures, they should be applied in the first instance to mitigating the environmental impact of aircraft engine emissions."*

Legal Ramifications of Emissions-related Levies

The proposed *"fuel levy"* and *"passenger ticket tax"* for international aviation in the AGF report do not address a critical challenge associated with the legal status of emissions-related levies for international aviation.

Generally, levies refer to charges and taxes. Article 15 of the Chicago Convention contains provisions regarding charges imposed by States for the use of airports and air navigation facilities, and its related ICAO policies (Doc 9082—*ICAO's Policies on Charges for Airports and Air Navigation Services*) make a conceptual distinction between a *"charge"* and a *"tax"*, in that a charge is a levy that is designed and applied specifically to recover the costs of providing facilities and services for civil aviation, and a tax is a levy that is designed to raise national or local government revenues which are generally not applied to civil aviation in their entirety or on a cost-specific basis.

AVIATION TAXES IN PERSPECTIVE

"A recent search for a flight from New York to London turned up an eye-catching fare: $229 each way on several airlines. But nine government taxes and fees added $162—more than a quarter of the total ticket price. Baggage fees may be the cause of more grumbling among passengers, but airlines are trying to draw attention to other charges lurking in the fine print: all the taxes and fees that go toward airport projects, air traffic control, airport security, customs inspections and, in some cases, projects that have nothing to do with flying—like a French "solidarity tax" on departing passengers that is meant to subsidize purchases of drugs to fight diseases like AIDS, tuberculosis and malaria in developing countries. Most of these taxes are small individually, but they can add up to a significant share of the price of a ticket, particularly for international flights…."

- New York Times, 1 March 2011,
"Taxes and Fees Grow for Air Travelers"

"For U.S. flights within the 48 contiguous states, the dollar value of total taxes and fees has remained relatively constant in real terms. The effective tax rate, which represents the relative share made up by these taxes, increased from 11% in 1993 to 16% by 2005. This was largely due to a significant reduction in average base fare (a 34% decrease from 1993 to 2005)…."

- MIT Airline Ticket Tax Project
http://web.mit.edu/TicketTax

[1] A workshop on this subject is planned from 18 to 20 October 2011 in Montreal - www.icao.int/SUSTAF

Article 24 of the Chicago Convention addresses the exemption of taxes on fuels, lubricants and other technical supplies onboard aircraft, and the related ICAO policies (Doc 8632—*ICAO's Policies on Taxation in the Field of International Air Transport*) recommend the reciprocal exemption from all taxes levied on fuel purchased for international flights. ICAO's policies also call on States to reduce or eliminate taxes related to the sale or use of international air transport.

In practical terms, the reciprocal exemption of taxes on fuel for international aviation has already been implemented in approximately 95 percent of the 4,000 existing bilateral air services agreements between States.

On 9 December 1996, the ICAO Council adopted a policy statement in the form of a Resolution, wherein the Council strongly recommended that *"any emission-related levies be in the form of charges rather than taxes, and that the funds collected should be applied in the first instance to mitigating the environmental impact of aircraft engine emissions,"* which is also in line with the recommendation of the 37th Assembly on the application of revenues.

Practical Challenges for Differentiation

The AGF report does not fully address the challenges associated with the possible differentiated application of MBMs for international aviation.

It should be recognized that several key characteristics of international aviation led to its inclusion in Article 2.2 of the Kyoto Protocol. While emissions from domestic aviation can be considered using the same approach applied to emissions from other sectors occurring within a State, emissions from international aviation differ as they are not contained within a single State and may occur within the territory of other States or in areas outside of recognized national boundaries, such as over the high seas.

HIGHLIGHTING AIR TICKET TAXES

International aviation is sometimes perceived as a less-taxed sector and targeted as an additional source of revenue for environment-related purposes. The list below identifies various types of air ticket taxes which have already been introduced in approximately 50 countries. These taxes are not necessarily earmarked for aviation or environment-related activities.

- *Air Passenger Tax*
  Six States (Australia, Ireland, Jamaica, Niger, Pakistan, Paraguay). Up to 34 Euros ($50) per passenger (PAX), depending on travel distance and international/domestic services.
- *Air Transportation Tax*
  Four States (Albania, Dominican Republic, U.K., United States). Up to 120 Euros ($176) per PAX, depending on travel distance, international/domestic services and travel classes
- *Civil Aviation Tax*
  Five States (Azerbaijan, Croatia, France, Sao Tome & Principe, Sweden). Up to 7 Euros ($11) per PAX, depending on travel distance, international/domestic services and travel classes.
- *Departure/Government Tax; Air Travel Levy*
  11 States (Austria, Armenia, Bermuda, Bosnia-Herzegovina, Egypt, Germany, Lebanon, Liberia, Mauritania, Syria, Ukraine). Up to 45 Euros ($66) per PAX, depending on travel distance and international/domestic services.
- *Development Tax*
  Three States (Benin, Cameroon, Gambia). Up to 22 Euros ($32) per PAX.
- *Solidarity Tax*
  10 States (Benin, Burkina Faso, Republic of Congo, France, Ivory Coast, Madagascar, Mali, Mauritius, Niger, South Korea). Up to 40 Euros ($59) per PAX, depending on travel distance, international/domestic services and travel classes.
- *Tourist Tax*
  19 States (Benin, Burkina Faso, Columbia, Congo Dem Rep, Costa Rica, Ecuador, El Salvador, Gambia, Ivory Coast, Jamaica, Mali, Mexico, Nepal, Nicaragua, Niger, Peru, Saint Kitts and Nevis, Venezuela, Yemen). Up to 21 Euros ($31) per PAX.

There has been a long, unresolved debate under the UNFCCC process over the allocation of international transport emissions to individual States and no agreement on the way to proceed has yet been reached. The differentiated application of MBMs for international aviation, as in the AGF report, would have clear implications on this debate.

Toward a Fair and Effective MBM Framework

Resolution A37-19 makes international aviation the first sector with global aspirational goals for improving annual fuel efficiency by two percent and stabilizing CO_2 emissions at 2020 levels. The Assembly also agreed on the development of a framework for MBMs, including further elaboration of the guiding principles, and decided to explore a global scheme for international aviation.

In addition, the agreement on the voluntary submission of States' national action plans to ICAO will allow States to identify a suitable basket of measures to reduce GHG emissions from international aviation as well as any assistance needs to implement such measures *(see Secretariat Article in previous ICAO Journal, Vol. 66, No. 2, p.30)*. Moreover, it was agreed that the Organization will study, identify and develop processes and mechanisms to facilitate the provision of technical and financial assistance, as well as facilitate access to existing and new financial resources, technology transfer and capacity building, to developing countries.

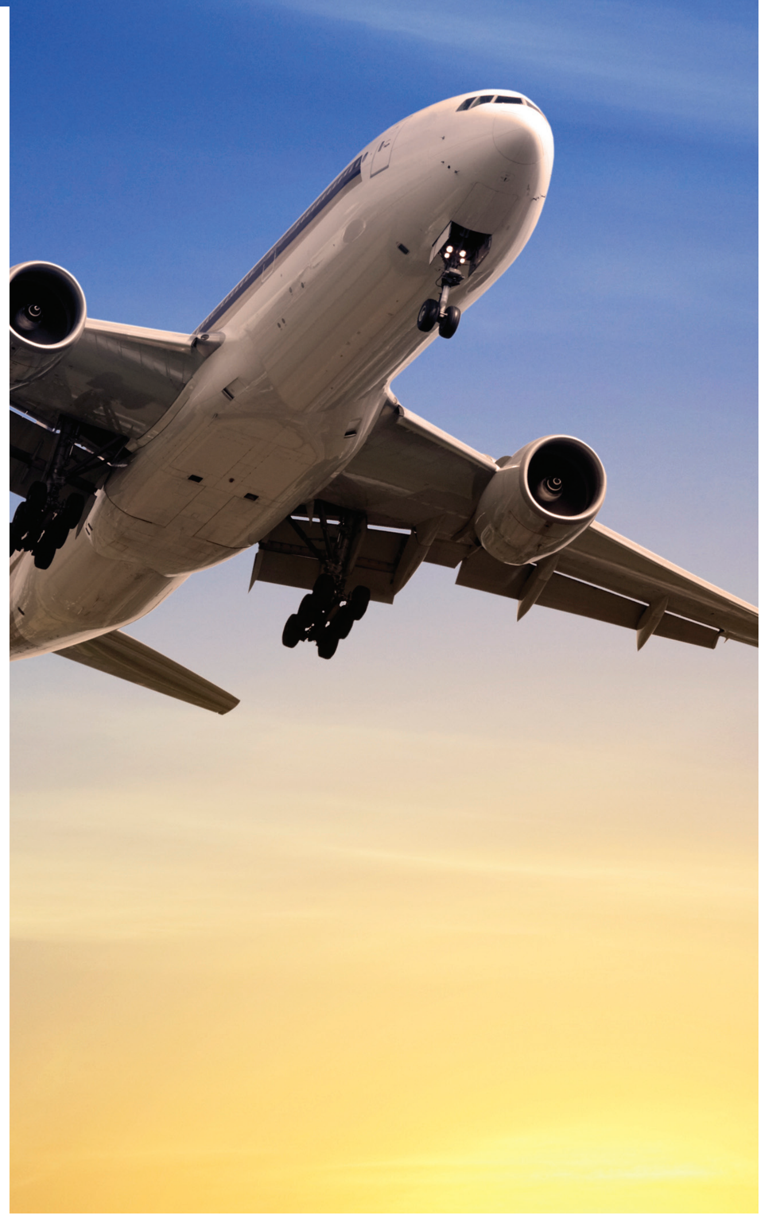
The lack of a decision under the UNFCCC process on how to address emissions from international aviation allows ICAO to move forward by making further progress on the actions requested by the Assembly. The design and implementation of MBMs for international aviation should be treated as one element of ICAO's comprehensive mitigation strategy to achieve aviation's global aspirational goals.

ICAO also needs to closely follow-up and cooperate with further work on the long-term climate financing under the UNFCCC process by keeping informed of related achievements and continuous sectoral efforts to limit or reduce CO_2 emissions from international aviation. The critical legal issues associated with emissions-related levies, as well as the practical challenges arising from the global nature of international aviation emissions, also need to be recognized. ICAO's work and leadership on an effective MBM framework for international aviation will be paramount in this regard. ■

Market-based Measures: Help or Hindrance?

IATA and the airline industry have adopted a four-pillar strategy for helping the air transport sector reach its GHG emissions targets: investing in new technology; improving the efficiency of aircraft operations; upgrading infrastructure; and the use of Market-based Measures (MBMs).

As Paule Steele, IATA's Director of Aviation and the Environment describes, the basic principles agreed at the 37th ICAO Assembly regarding an effective MBM framework represents an excellent starting point as air transport moves toward this objective, but only a globally-harmonized and inclusive set of economic emissions guidelines will be able to guarantee a fair and effective outcome for both aviation and the environment.



Paul Steele is Director Aviation Environment at the International Air Transport Association (IATA). He is responsible for guiding and implementing IATA's environment strategy worldwide. He is also Executive Director of the Air Transport Action Group (ATAG) a cross-industry body that promotes sustainable aviation. Prior to joining IATA in December 2007, Steele was Chief Operating Officer of WWF International and is a former faculty member of the Prince of Wales' Business and the Environment Programme run by Cambridge University. He has over 20 years of senior management experience with major international companies, including as Chief Executive of The Virgin Trading Company, Senior Vice President Sales, Marketing and Information Technology of the Hilton Hotel Group and various senior roles at Pepsi Cola International, lastly serving as Group Vice President in charge of Northern Europe.

The aviation industry recognizes its crucial role in helping to stabilize and reduce GHG emissions. It is in fact the only industry to date to set global targets and a clear strategy to mitigate the two percent of man-made CO_2 emissions from the sector. The aviation community's three targets, commended by UN Secretary General Ban Ki-moon, are:

1. To improve fuel efficiency by an average of 1.5 percent per year to 2020.
2. To cap net carbon emissions from 2020 through carbon-neutral growth.
3. To reduce net carbon emissions by 50 percent by 2050 compared to 2005.

“IATA’s position is clear. It sees a role for positive economic instruments and is keen to work through ICAO to bring industry and policy-makers together to create a consensus around a global approach. We have much experience in seeing what works and what doesn’t work in terms of economic measures and the evidence increasingly supports our view.”

Delivering on these ambitious targets will require substantial investments on the part of the industry and the support of governments in upgrading infrastructure. IATA and the industry have adopted a four-pillar strategy for reaching the targets, namely: investing in new technology; improving the net efficiency of operations; upgrading infrastructure; and the use of positive economic instruments or ‘Market-based Measures’ (MBMs).

Regardless of the terminology, the industry has always recognized that some form of economic measure would be one of the tools used to help reach our emissions targets.

Why a Global Industry Needs a Global Approach

Aviation is a truly global industry providing connectivity for passengers and trade around the world. As in other areas, such as air transport safety and operations, it is imperative that any measures aimed at improving aviation’s environmental performance be applied in a manner which is consistent and harmonized. If that is not ensured then inefficiencies and competitive distortions will result and this principle is especially important with respect to economic or market-based measures.

With a plethora of different taxes, charges and emissions trading schemes either in place or on the drawing board across the world, the air transport industry has been pushing hard for these to be replaced by one single global approach, as foreseen by ICAO. Such an approach would simplify matters for both airlines and passengers while ensuring that aviation as a sector is treated fairly and pays for its emissions only once.

This need for fairness must be stressed, as at present aviation is being caught in a multi-taxation trap, with numerous levels of local, national, regional and potentially international taxes or charges being levied under the ‘environment’ umbrella. No sector should be made to pay more than once for addressing the same emissions, but unfortunately this is exactly what is happening today with respect to aviation.

Examples of this include the imposition of regional emissions trading schemes on top of national state taxation. Under such a framework the passenger pays twice for the same emissions and yet with no guarantee that the funds being remitted are being used for environmental purposes.

Above all, governments must avoid the fallacy of believing that economic measures in and of themselves will adequately reduce or control emissions. Economic tools can only be effective as part of a basket of measures that address all four pillars of the emissions reduction strategy.

A Single, Globally-harmonized MBM Regime

Economic measures come in many shapes and sizes and they are not all equally effective in reducing emissions. Some economic measures which are billed as ‘green’ are simply revenue-raising taxes for central treasuries. These have no measurable impact on emissions and can be actually counter-productive in that they reduce the funds that could otherwise be made available for the industry to invest in cleaner technology—something aviation has done better than any other transport sector over the past several decades. Furthermore, if poorly designed, MBMs can cause market distortions and effectively put a tax on economic development for developing countries which rely on aviation for trade, tourism and inward investment.

Other economic measures, such as Emissions Trading Schemes (ETSs) or carbon funds, can potentially be more effective but they must be properly designed and globally implemented. The imposition of measures by one region or country on another is bound to cause problems, leading to disputes and tit-for-tat retaliatory actions between affected countries.

In order to avoid the emerging GHG regime, whereby the double-counting of emissions and administrative confusion become the direct result of poorly-harmonized, inconsistent and duplicative measures both nationally and internationally, the industry firmly supports ICAO in developing plans for a globally-harmonized economic environmental measure by 2020.

IATA welcomes the first steps made last year at the ICAO 37th Assembly whereby State delegates agreed a framework of basic principles, or tests, which any economic measure should meet *(see page 14)*.

The guiding principles agreed by the 37th ICAO Assembly for the design and implementation of Market-based Measures (MBMs) for international aviation:

a) MBMs should support the sustainable development of the international aviation sector.
b) MBMs should support the mitigation of GHG emissions from international aviation.
c) MBMs should contribute towards achieving global aspirational goals.
d) MBMs should be transparent and administratively simple.
e) MBMs should be cost-effective.
f) MBMs should not be duplicative and international aviation CO_2 emissions should be accounted for only once.
g) MBMs should minimize carbon leakage and market distortions.
h) MBMs should ensure the fair treatment of the international aviation sector in relation to other sectors.
i) MBMs should recognize past and future achievements and investments in aviation fuel efficiency and in other measures to reduce aviation emissions.
j) MBMs should not impose inappropriate economic burdens on international aviation.
k) MBMs should facilitate appropriate access to all carbon markets.
l) MBMs should be assessed in relation to various measures on the basis of performance, measured in terms of CO_2 emissions reductions or avoidance, where appropriate.
m) MBMs should include *de minimis* provisions,
n) Where revenues are generated from MBMs, it is strongly recommended that they should be applied in the first instance to mitigating the environmental impact of aircraft engine emissions, including mitigation and adaptation, as well as assistance to and support for developing States.
o) Where emissions reductions are achieved through MBMs, they should be identified in States' emissions reporting.

These principles, adopted in the 37th Assembly Resolution, clearly set out the requirements for effective economic measures. IATA is keen to see ICAO's Member States move forward to develop a more detailed framework for MBMs with the ultimate objective of a single measure for aviation to be put in place as soon as possible.

In IATA's view only a truly global economic tool—or one accessible to all across the globe—can guarantee a fair and effective outcome for both aviation and the environment. Any measures put in place must bring about demonstrable reductions in emissions and any revenues raised from such measures should be mandated to be reinvested back into the aviation sector for research and development to accelerate emissions reductions and to provide assistance to those States that require help in making their industry more sustainable.

Further, any economic measure should have a 'sunset clause' to provide for its discontinuation in the event that aviation meets its environmental obligations through other means.

Looking Ahead

This year IATA will release a series of economic reports, written by the respected independent economic forecasters at Oxford Economics, on the benefits of aviation. Country by country, each report (more than 50 in total) will investigate the socio-economic contributions of aviation and the consequences of negative economic measures on air transport effectiveness. The evidence to date, echoed by experiences in Ireland and the Netherlands, suggests that governments lose more in revenues associated with economic growth than they gain through ticket taxes. In this respect IATA argues that ticket taxes are neither environmentally nor economically sustainable.

So IATA's position is clear. It sees a role for positive economic instruments and is keen to work through ICAO to bring industry and policy-makers together to create a consensus around a global approach. We have much experience in seeing what works and what doesn't work in terms of economic measures and the evidence increasingly supports our view.
We were pleased that the ICAO 37th Assembly endorsed the principles for MBMs, and we are confident that, if these guidelines are applied properly, an effective global approach for reducing carbon emissions can be put in place.

We urge Member States within ICAO to continue to work on this important element of the four pillars of environmental achievement and IATA stands ready to assist in any way possible. ICAO has a unique window of opportunity to build on the success of the 2010 Assembly and on the heightened reputation of aviation at the UNFCCC—as a sector that is taking its environmental responsibilities seriously and is leading the way with positive solutions.

Industry can only do so much in this regard and ultimately it is regulators at the national and global level that have to act. Delay is no longer an option. ■


Effective Global Leadership
Through Balanced Priorities

Aviation Impacts of the New Zealand Emissions Trading Scheme

The New Zealand Emissions Trading Scheme represents that State's key mechanism to establish a price for greenhouse gas emissions.

Under the scheme, airlines that purchase large amounts of jet fuel for domestic use may voluntarily opt-in to the scheme. In doing so, they take on all the legal obligations that would otherwise be held by their fuel suppliers.

As Jörn Scherzer and Melanie Hutton of the New Zealand Ministry of Transport report, these ETS mechanisms on fuel present an incentive for airlines to review areas where they can increase efficiencies and optimize operations to reduce fuel usage. In this way the mechanisms promote measures such as biofuel investment and the use of more efficient aircraft, helping to reduce ETS financial impacts.

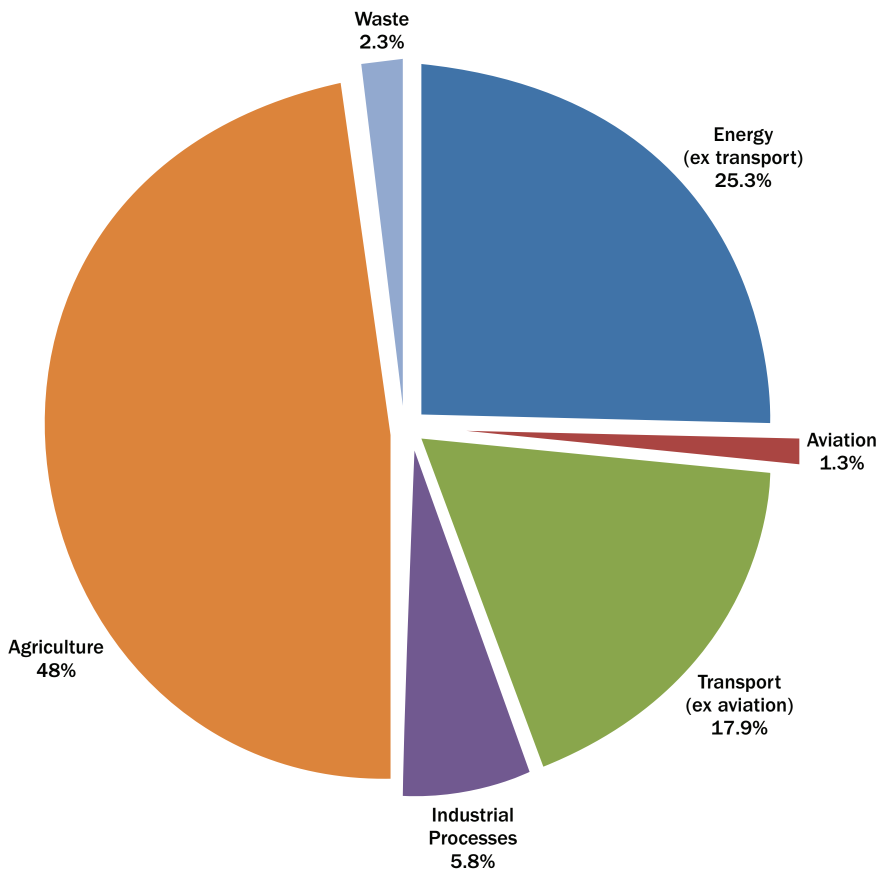
Jörn Scherzer is an Adviser at the New Zealand Ministry of Transport. He leads the transport sector work on the Emissions Trading Scheme and was directly involved in the development of the scheme. Before joining the Ministry of Transport in early 2008, he was a Research Fellow at the Ecologic Foundation working mainly on climate change issues.

Melanie Hutton is a Senior Adviser at the New Zealand Ministry of Transport. She leads the work on the treatment of international transport fuel emissions for the New Zealand government. Her previous job was as Climate Change Manager for WWF New Zealand.

The New Zealand Emissions Trading Scheme (ETS) establishes a price for greenhouse gas emissions and assists the New Zealand government in meeting its obligations under the Kyoto Protocol.

The scheme covers the forestry, energy, industrial processes and transport sectors (domestic aviation only). The forestry sector entered the scheme on 1 January 2008 and the other sectors followed suit as of 1 July 2010. As shown in Figure 1 *(right)*, the ETS presently covers approximately 50 percent of New Zealand's greenhouse gas emissions. Remaining sectors, including waste management and agricultural activities, will also be included in the scheme over time.

Figure 1: New Zealand's Emission Profile (2008)



How the ETS Works

In the New Zealand emissions scheme, participating firms must hold, and on an annual basis surrender to the government, a number of emission units[1] (also known elsewhere as 'allowances'). These units or allowances are equivalent to the emissions each of the firms is responsible for on a yearly basis.

Firms can buy or sell emission units in the commercial trading market, although some restrictions regarding the export of emission units apply between 1 July 2010 and 31 December 2012. In some circumstances, firms can receive emission units for free from the government—provided they meet certain conditions.

The primary unit of trade for the emissions trading scheme is the New Zealand Unit (NZU), which was created and is presently issued by the New Zealand government. One NZU is equivalent to one tonne of carbon dioxide emissions.

The New Zealand ETS is linked internationally with similar programmes established by Kyoto Annex B countries. 'Annex B countries' refers to the industrialized States (including some Central European countries with transitional economies) listed in Annex B of the Kyoto Protocol. Annex B States must have agreed to the legally binding Kyoto reductions in greenhouse gas emissions of an average of 6 to 8 percent below 1990 levels between the years 2008–2012.

Apart from the New Zealand NZU, several types of international Kyoto units can also be used by ETS participants to meet their obligations under the New Zealand scheme, namely:

- *Emission Reduction Units (ERUs)* generated by Joint Implementation projects that reduce emissions or create forest sinks in Annex B countries.
- *Removal Units (RMUs)* awarded to Annex B countries on the basis of net removals by carbon sinks in the land use, land-use change and forestry sector.
- *Certified Emission Reductions (CERs)* generated by Clean Development Mechanism projects that support sustainable development and reduce emissions or create forest carbon sinks in developing countries.[2]

The cost of Kyoto emission units creates a price signal to companies and consumers to change their behaviour and reduce emissions. Figure 2 *(p.19)* illustrates how the scheme operates in practice.

Impacts for Airlines

In the transport sector, large fuel suppliers must participate in the scheme

"Requiring fuel suppliers to meet these obligations, rather than consumers and transport companies, minimizes compliance and administration costs. This is because an upstream point of obligation captures most of the sector's emissions, simplifies the monitoring of emissions and reduces the number of participants. At present, there are only five mandatory participants in the transport sector."

and purchase emission units to cover the emissions that result from the fuel they sell.[3]

Requiring fuel suppliers to meet these obligations, rather than consumers and transport companies, minimizes compliance and administration costs. This is because an upstream point of obligation captures most of the sector's emissions, simplifies the monitoring of emissions and reduces the number of participants. At present, there are only five mandatory participants in the transport sector.

The scheme also allows airlines that purchase large amounts of jet fuel for domestic use to voluntarily opt-in to the scheme. In doing so, they take on all the legal obligations that would otherwise be held by their fuel suppliers. This includes the surrender of emission units corresponding to the amount of fuel they use, annual reporting, and the maintaining of suitable records for at least four years. At present, Air New Zealand is the only voluntary participant in the transport sector.

Consumers, as well as companies such as flight schools, logistics firms or public transport operators, do not directly participate in the emissions trading scheme. They do, however, experience the effects of the scheme through marginally higher fuel prices.

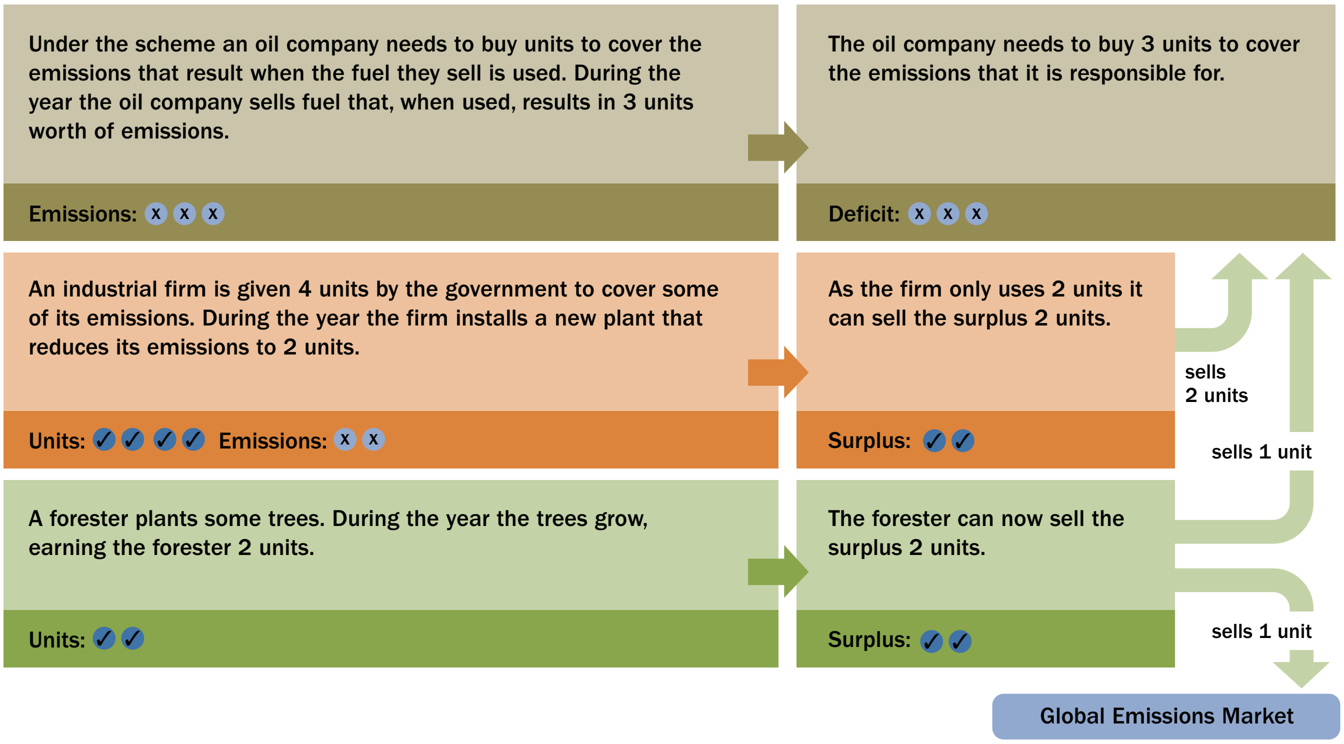
Importantly, all fossil fuels (and correspondingly all transport modes) are covered by the scheme; i.e. petrol, automotive and marine diesel, aviation gas, jet fuel, light fuel oil, and heavy fuel oil. There are also two key exemptions: biofuels and fuel used for international aviation/maritime transport[4] are not covered by the scheme. Additional fuels with less significant climate impacts, such as lighting kerosene, solvents and lubricants, are also exempt.

TABLE 1: SCENARIOS OF CARBON PRICE EFFECTS

		'Carbon' Emission Price Scenarios		
Fuel	**Emission factor tCO_2e/1000litres**	**NZ$12.50/$tCO_2e$** *(max cost increase between 1 July 2010 and 31 Dec 2012)*	**$NZ25/$tCO_2e$**	**$NZ50/$tCO_2e$**
Petrol: *Additional cents/litre*	2.310	NZ$0.02.9	NZ$0.05.8	NZ$0.11.6
Heavy fuel oil: *Additional cents/litre*	3.015	NZ$0.03.8	NZ$0.07.5	NZ$0.15.1
Jet fuel: *Additional cents/litre*	2.525	NZ$0.03.2	NZ$0.06.3	NZ$0.12.6

tCO_2e = tonnes carbon dioxide equivalent   One New Zealand dollar = $0.75; NZ$0.03 = $0.02.25 (March 2011)

Figure 2: How Emissions Trading Works in New Zealand



Costs and Incentives

In the transport sector there is no free allocation of emission units; i.e. fuel suppliers must buy units to cover all of the emissions that result when the fuel they sell is used. While some emission units are allocated for free in other sectors (e.g. aluminium production), where a carbon price may cause production from emissions-intensive, trade-exposed sectors to shift from New Zealand to countries without an equivalent carbon pricing regime, this does not apply to the transport sector.

As a result of the ETS, fuel prices are slightly higher than they otherwise would be. The maximum price increase for the first two and a half years of the scheme's operation is $0.03.5 New Zealand dollars per litre ($0.02.6 per litre). This is because between 1 July 2010 and 31 December 2012 the scheme features a lower emissions price and a reduced obligation.[5] This is activated by an emissions price cap of NZ$25.00 per tonne ($18.75 per tonne) and a 50 percent 'progressive' obligation, which is a requirement to surrender only one emission unit for every two tonnes of emissions.

From 1 January 2013, liquid fossil fuel prices will reflect the cost of emission units on the international market. Table 1 shows emission price scenarios and the corresponding additional cost on fuel for different fuels in New Zealand.

The fuel price increases present an incentive for consumers and companies to review areas where they can increase efficiencies, optimize operations and reduce fuel usage. By increasing efficiency businesses can get better value for money and manage the effect of the ETS.

For instance an airline may wish to either invest in biofuels to reduce its reliance on fossil fuels, or buy more efficient planes to increase fuel efficiency. In this way the airline would reduce its financial impact due to the ETS.

More information on the New Zealand Emissions Trading Scheme is available at: **www.climatechange.govt.nz** ■

Footnotes:

1 Emission units are stored and managed through the New Zealand Emission Unit Registry (www.eur.govt.nz). All participants in the emissions trading scheme must have an account in the registry.

2 There are some restrictions, for example, certified emission reductions from nuclear project activities are not permitted.

3 Methodological details and emission factors can be found in the Climate Change (Liquid Fossil Fuel) Regulations 2008, see www.legislation.govt.nz.

4 This only applies to international transport; all fuel used for fishing activities is covered by the ETS.

5 During this transition phase the export of units from the stationary energy, industrial processes and liquid fossil fuels sectors is not permitted so as to reduce arbitrage opportunities.

First Workshop on Action Plans to Reduce CO_2 Emissions from Aviation

The first in a series of regional training workshops to assist ICAO Member States in producing national action plans for reducing CO_2 emissions from international civil aviation was held from 2–4 May in Mexico City, Mexico.

"ICAO environmental action plans will help States identify the most appropriate measures to reduce emissions from international aviation. They will also allow ICAO to monitor progress by States in achieving global aspirational goals and help address specific needs through technical and financial assistance," said the Organization's Council President, Roberto Kobeh González, in his opening address.

The plans, to be submitted to ICAO by June 2012, result from an agreement reached at the 37th Session of the ICAO Assembly last fall which made international aviation the first sector with global aspirational goals of stabilizing CO_2 emissions at 2020 levels and achieving a 2 percent annual increase in fuel efficiency up to 2050.

The Organization has prepared a comprehensive programme to assist States in developing their action plans, which includes guidance material, a web-based template for the submission of action plans, and workshops to provide information and training in the preparation of action plans by focal points nominated by States.

"The ICAO workshops provide an opportunity for the exchange of views and experiences in order to help States formulate policies and measures that are in line with differing realities," commented Ambassador Juan Manuel Gómez Robledo, Undersecretary for Multilateral Affairs and Human Rights.

"ICAO is without a doubt an organization at the forefront of the global fight for the reduction of international aviation emissions. This was demonstrated when it proposed at its 37th Assembly the creation of a global plan of action on climate change based on national plans," added Felipe Duarte Olvera, Undersecretary of Transport.

Hosted by the government of Mexico, the workshop is attended by representatives from North, Central and South America and the Caribbean States nominated by their governments to act as focal points in the development of their respective State action plans. Other stakeholders such as regional civil aviation organizations, the Inter-American Development Bank, the International Air Transport Association (IATA), Airports Council International (ACI) and the Civil Air Navigation Services Organisation (CANSO) are also contributing to the workshop.

Regional workshops are planned later this year for Bangkok (25–27 May), Dubai (14–16 June), Nairobi (4–6 July) and Paris (11–13 July). These intense efforts will make it possible for all ICAO regions to receive the initial information necessary to launch the preparation of their action plans by midyear.

Signature by France of 2010 Beijing Convention and Protocol

On 15 April 2011, France signed the *2010 Beijing Convention on the Suppression of Unlawful Acts Relating to International Civil Aviation* and the *2010 Beijing Protocol to the 1970 Hague Convention on the Suppression of Unlawful Seizure of Aircraft*. This brought the number of signatures to 21 and 23 respectively.

Shown on the occasion *(from left to right)* are: Michel Wachenheim, Ambassador, Representative of France on the Council of ICAO; and Denys Wibaux, Director, ICAO Legal Affairs and External Relations Bureau.

UPCOMING ICAO HQ EVENTS

Meeting	Site	Dates
Fatigue Risk Management Systems Symposium and Forum (FRMS)	ICAO Headquarters, Montréal	30 August–2 September 2011
Symposium and Exhibition on MRTDs, Biometrics and Security Standards (MRTD Symposium)	ICAO Headquarters, Montréal	12–15 September 2011
Global Air Navigation Industry Symposium (GANIS)	ICAO Headquarters, Montréal	20–23 September 2011
ICAO Air Services Negotiation Conference (ICAN/2011)	Mumbai, India	17–22 October 2011
ICAO Workshop on Aviation and Sustainable Alternative Fuels (SUSTAF)	ICAO Headquarters, Montréal	18–20 October 2011

A Reality Check on Alternative Aviation Fuels

The SWAFEA European Study

The European Union's Sustainable Way for Alternative Fuels and Energy in Aviation (SWAFEA) study has been investigating the feasibility and the impact of the use of alternative fuels in aviation based on multidisciplinary technical, environmental, and economic assessments.

Given the uncertainties surrounding the availability of cheap and sustainable feedstocks, the study highlights that achieving the industry target of halving emissions by 2050 (compared to 2005 levels) will require significant further research and innovation in order to isolate suitable sources of biomass and improve related processes, efficiencies and the overall economic viability.

Although aviation today is a minor contributor to world GHG emissions, the projected growth in air traffic, if not more significantly decoupled from CO_2 emissions growth, could serve to undermine future progress made by other sectors in combatting climate change.

The European Union has been committed to taking an active role in climate change mitigation through the promotion of secure and sustainable energy sources that contribute to reductions in greenhouse gas (GHG) emissions. Reducing energy dependence, increasing security of supplies and contributing to economic growth are key EU objectives in this regard and alternatives to crude oil-based kerosene are seen as important components in some of the efforts now being directed to improving aviation's carbon footprint.

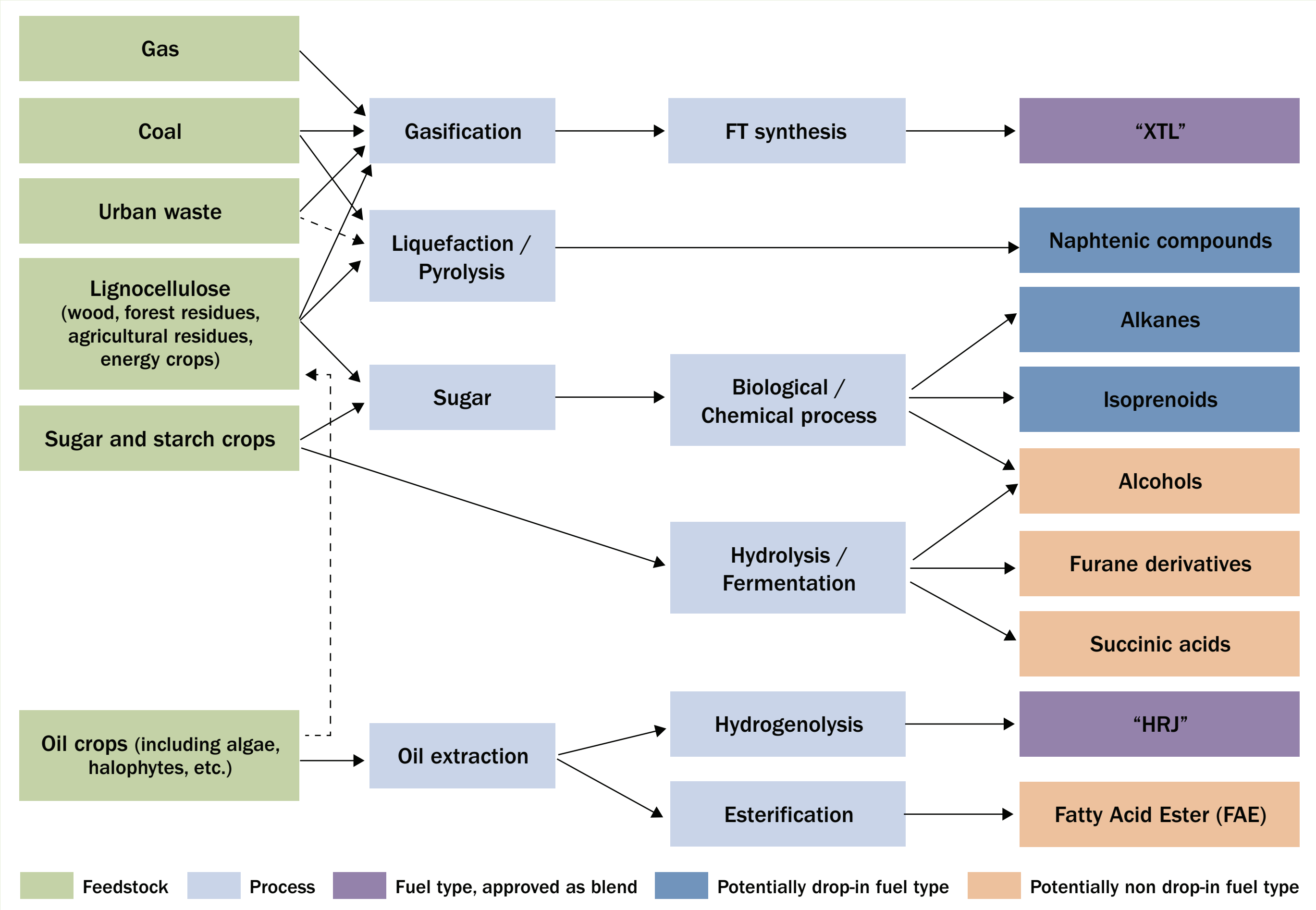
Corresponding to these objectives, in February 2009 the European Commission's Directorate General for Mobility and Vehicles (formerly the Directorate General for Energy and Transport) initiated the Sustainable Way for Alternative Fuels and Energy in Aviation (SWAFEA) study to investigate the feasibility and impacts of the use of alternative fuels in aviation. The goals were to develop a comparative analysis of different fuels and energy-carrier options for aviation on the basis of current knowledge, as well as to propose a possible vision and roadmap for their deployment in order to facilitate and support future policy decisions.

The SWAFEA study encompassed all aspects of the possible introduction of alternative fuels in aviation using a highly multidisciplinary approach. This included technical, environmental, and economic assessments. The purpose of the technical component of the study was to complement available data regarding technical suitability with additional investigation and testing. The environmental and economic assessments both consisted of in-depth analyses of the impact of various fuel production pathways, from feedstock to fuel, through the entire life-cycle. The environmental component also included societal impacts of fuel production, while the economic component studied the required fuel production infrastructure in addition to the cost breakdown of various alternative fuels.

The study was carried out under the leadership of French Aerospace Research Lab ONERA, in cooperation with a consortium of twenty partners. It brings together European research organizations and representatives of virtually every major stakeholder in the aviation fuel chain. Major European aircraft and engine manufacturers, namely AIRBUS, ROLLS-ROYCE and SNECMA, in addition to Brazil's EMBRAER, participated in this study together with EADS's research and innovation entity—EADS Innovation Works—and Bauhaus Luftfahrt, the Bavarian aviation think-tank.

LIQUID FUEL PRODUCTION PATHWAYS

In addition to refining conventional crude oil, many production pathways for liquid fuels have been proposed. They are illustrated in the following figure. The fuel types which are currently seen as having the best potential for aviation use are highlighted in blue.



Source: SWAFEA

Fuel producers were represented by Shell and the European association of refiners, CONCAWE, while AIR FRANCE and IATA represented the airlines as end customers of aviation fuels. The research organizations involved included DLR (the German Aeropace Centre), the University of Sheffield, IFP Energies Nouvelles (the French research organization for fuel and energy), INERIS (the French research centre for risk and security), CERFACS (the European centre for research and advanced training in scientific computation), and Plant Research International from the Wageningen University and Research Centre. Two consultancy companies, ALTRAN and ERDYN, rounded out the team.

The results of the study were presented and discussed during the SWAFEA synthesis conference held in Toulouse from 9 to 10 February 2011, where a number of stakeholders, including ICAO, participated to panels and round tables to debate conclusions and further orientation. Following this the final report and recommendations were delivered to the European Commission in April 2011.

Fuel Technical Assessment

The aim of the technical work performed within the study was to investigate the properties and performance of generic fuel solutions in order to evaluate their potential suitability for aviation. Investigations carried out on the different fuel types were mainly based on an experimental testing programme designed to answer key questions regarding the short- to mid-term development of alternative fuels for aviation. This testing programme was not intended to be an approval programme and, consequently, it included a selection of important tests but did not go through the approval process defined in ASTM D4054.

The purpose was to go beyond the Fischer-Trospch Synthetic Paraffinic Kerosene (SPK—already approved as a 50 percent blending agent with Jet A-1) and Hydroprocessed Renewable Jet (HRJ—a SPK obtained from vegetable oil hydropro-cessing and also currently under approval as a 50 percent blend with Jet A-1). The

EXCERPTS FROM JANE HUPE'S (CHIEF ENVIRONMENT BRANCH, ATB, ICAO) KEYNOTE ADDRESS AT THE SWAFEA SYNTHESIS CONFERENCE (TOULOUSE, FRANCE, 9–10 FEBRUARY 2011)

"It is essential that we develop an understanding and agreement on vital questions covered in the SWAFEA study and, for three years now, ICAO has been promoting information sharing on all major issues related to the development and deployment of alternative fuels."

"SWAFEA has already taught us a great deal about the potential benefits of sustainable alternative fuels in aviation and has emphasized the need for our sector to make informed decisions. ICAO can facilitate the global harmonization of initiatives and measures that will ensure that this new energy source for aviation helps to move our sector towards sustainability."

focus of these technical investigations was nevertheless limited to potential drop-in fuels, meaning fuels for which expectations are high with respect to their ability to demonstrate compatibility with current systems, in either neat or blended forms and in significant amounts with Jet A-1.

It should be noted that, with respect to mid-term objectives, the SWAFEA consortium was not able to identify any non-drop-in fuel candidate that could deliver the significant technical, environmental or economic advantages that would allow it to overcome the persistent operational drawbacks and costs associated with non-drop-ins.

Investigations revealed that an increasing SPK blending ratio (free of aromatics) could result in incompatibilities with current aircraft[1] and in operational problems because of the low density of SPK present. This is despite the fact that reduced aromatic content is favourable for engine particulate emissions.

Results for new pathways that provide non-conventional sources of aromatic compounds (liquefaction/pyrolysis, etc.) indicated that synthetic aromatics are indeed viable blendstocks, though further study is needed in order to demonstrate this viability.

The preliminary test performed with a fit-for-purpose HRJ (produced by IFPEN and Shell) also identified the possibility of trade-offs between economic and product properties with regard to low blending ratios with Jet A-1 in an initial deployment phase.

In addition, results were obtained for a blend of Jet A-1 with a 10 percent volume of fatty acid ester in the kerosene cut (i.e., FAE molecules with similar carbon chain lengths as in kerosene). It provided information concerning the impact of oxygenated molecules in the fuel and illustrated the associated challenges.

Due to their novelty, the sugar derived hydrocarbon routes could not be assessed within SWAFEA. Following recent announcements and the progress being made by U.S. biofuel start-ups, these pathways are certain to be considered in future studies.

Environmental Assessment

Within the SWAFEA study, two types of environmental assessments were carried out: one focusing on the atmospheric impact of alternative aviation fuels; the other on their life-cycle emissions and environmental/societal sustainability.

Aircraft emissions can perturb the atmospheric chemistry and the radiative balance of the atmosphere via soot and NO_x/SO_x emissions, which impact ozone and contrail formation. The most recent evaluations of those effects reveal the existence of a greenhouse amplification factor. This is to say that the greenhouse gas molecules emitted from a jet aircraft can induce a greater amount of radiative forcing than similar molecules emitted at ground level.

Measurements of soot particle numbers from engine exhausts using alternate bio-fuels have demonstrated a significant reduction in the concentration of soot particles emitted. This reduction would be in the range of 30 to 50 percent when a 50 percent blend of HRJ with Jet-A1 is used. Modelling results reveal that the effect of this reduction of sulphur and soot particles could significantly reduce the global radiative forcing from linear contrails when this type of fuel is employed. These results only represent a fraction of the complete picture, however, and additional testing and modelling are required to fully understand the impact of related emissions on the atmosphere. Conversely, the impact of the considered fuel on ozone formation, through NO_x, CO and unburned hydrocarbons, is expected to be modest.

The Life Cycle Analysis (LCA) focused on currently known and mature pathways for alternative aviation fuels: Fischer-Tropsch and Hydrotreated Renewable Jet fuel (HRJ) routes. Within the EU's Renewable Energy Directive (RED), only alternative fuels with LCA GHG emissions 60 percent (or more) lower than conventional fuel will be considered eligible to count towards renewable energy targets. This minimum requirement for biofuels is more easily obtained with BTL than with HRJ pathways. BTL, however, demonstrates low energy yields per MJ_{fuel} and is thus biomass intensive. HRJ results, meanwhile, vary significantly depending on the feedstock. In general, GHG emissions predominantly (>70 percent) originate from crop management (fertilization and mechanization). The same is the case for algae, although integration with other activities for energy, CO_2, and nutrient requirements may greatly improve the results.

Additionally, Land Use Change (LUC) has a highly variable impact on LCA emissions. Depending on soil types, climate conditions and vegetation, LUC may invoke a high carbon release that could completely negate the pathway emissions reductions by a factor of 3 to 5. It is also possible that LUC to perennial species could become a positive factor, resulting in emissions reductions.

[1] Seals in the fuel systems of current aircraft need a certain aromatic content to prevent leakage.

"Biofuels can contribute to aviation GHG emission reductions and to the diversification of the sector's fuel supply, but achieving significant reductions will require time and a determined political will. Initiatives have to be decided in the very near-term to start the process and generate the learning and technological progress which is required to enable a more accelerated future deployment and achieve current 2050 emissions reductions targets."

Controlling LUC is a major issue to achieve emissions reductions, however indirect LUC may also result from crop displacement. No commonly accepted methodology currently exists to assess ILUC—a key persisting challenge to biofuel sustainability.

The potential availability of biomass for energy is another fundamental aspect of biofuel sustainability. It was assessed for agriculture, forestry and waste through 2050 and conservative choices were selected to prevent over-estimations. Sustainability criteria, such as no deforestation, croplands only, and the availability of grazing land after securing of regional food supplies were used.

Based on these assessments, agriculture reveals itself to be the main source of biomass but it also requires significant levels of development and the intensive cultivation of large amounts of land. Fertilizer and manpower availability also factor in as agricultural suitability prerequisites. It was concluded, however, that achieving the aviation industry target of halving aviation emissions by 2050 (compared to 2005 levels) would call for an excessive allotment of the potentially-available biomass if only the current transformation technologies and this 'traditional' biomass were considered.

The target of stabilizing emissions at their 2020 level before 2050 (carbon-neutral growth) appears to be a more feasible target without considering very radical innovation. In any case, it will be a difficult challenge to scale up to the required production levels of sustainable biomass within the next 40 years. Research on additional options, such as algae or other innovative pathways, is thus a key for biofuel development.

With the exception of competition with food, potential environmental and societal impacts don't appear to be intrinsic features of either biofuels or the crops used to produce them. Risks are mostly relevant for agriculture management and the development of associated policies in the interested countries. The fact is that biofuels development may put additional pressure on existing trends linked to intensive agriculture development (deforestation, water demand, etc.). Certification seems to be the main tool to mitigate the potential negative impacts of biofuels and to ensure they are produced in a sustainable manner. Comprehensive frameworks already exist for such certification, while the handling of indirect effects still requires further methodological work. The existence of multiple environmental regulations, LCA methodology and certification schemes for a global activity like aviation may induce difficulties. Further harmonization in this regard would help to facilitate eventual deployment.

The Economics of Alternative Fuels

In order to meet the industry target of halving aviation CO_2 emissions by 2050 compared to 2005, approximately 67Mt of the annual European fossil fuel-based jet fuel consumption would need to be saved by 2050. This figure already factors in the expected improvements to aircraft fleet efficiency. Currently known technologies and operational measures are significant but insufficient to reach these emissions targets and therefore increased mitigation through biofuel introduction will likely be required.

With the current view on biojet fuel technology, this translates into required alternative fuel production infrastructure of approximately 80 HRJ plants, 290 BTL plants or some combination of the two for only the European jet fuel market. This would require a total investment of 150–800 billion Euros ($217 billion – $1.15 trillion) over the coming 40 year period, depending on how many plants of each type would be built. Of this investment, $45-290 billion would have to be covered by aviation, as only a fraction of the plant output would likely be aviation fuel (the remainder being diesel and light ends). The sheer scale of these numbers shows the importance of the challenge, especially in consideration of the fact that they only consider the aviation fuel demand for the European region.

Feedstock prices have a strong impact on the financial viability of alternative aviation fuels. In the financial model developed within the framework of the SWAFEA study, if feedstock prices were to increase at the same rate as projections for crude oil, BTL biofuels would only reach price parity with conventional jet fuel plus ETS emission rights by 2040, while HRJ would not reach parity at all before 2050 (and for some time beyond). If feedstock prices were to decrease in conjunction with expected crop yield improvements, both BTL and HRJ would reach price parity (mid-2020s for BTL; late-2030s for HRJ). Cheap and available sustainable feedstock is the most important bottleneck now facing the introduction of biofuels in aviation.

Even in the case of low feedstock prices, the economical analysis shows that neither BTL nor HRJ solutions are initially cost-competitive with conventional jet fuel. In addition, the BTL process requires huge capital investment which adds a barrier for deployment. Specific measures are thus needed to enforce biofuel deployment and the introduction of aviation into the current EU Emissions Trading Scheme (ETS) doesn't portend to be a sufficient incentive.

Currently, little data on sugar-based routes are available in the public domain but analysis has indicated that biological routes have good potential to become economically-viable in the mid- to long-term (although low efficiency is currently a significant bottleneck). The investigated routes, however, are still in the R&D stage and development is required prior to any significant scale-up.

The production of biofuels for aviation is also linked to the production of biofuels for other transport modes, in particular road transport but also maritime transport. Indeed, both for technical and economic reasons, the exclusive production of biomass-based jet fuel cannot be considered as viable based on existing BTL and HRJ processes (conversely biodiesel production doesn't imply jet fuel production).

The profitability of biofuels in the other transport sectors is thus an important parameter of the jet biofuel business case. The market demand and regulatory/tax context of this sector is therefore significantly tied to the viability of aviation biofuel production, with both synergy and competition existing between aviation and other modes of transport in this regard.

Conclusion and Perspective

Considering that aviation has no other energy solutions besides liquid fuel sources and will not succeed in reducing its emissions through efficiency gains alone, biofuels are likely to play a key role in the future. Given the uncertainty about the availability of cheap and sustainable feedstocks, however, achieving the industry target of halving emissions by 2050 compared to 2005 will require a significant research effort along innovative pathways to find additional sources of biomass and improve both process efficiencies and economic viability.

Biofuels can contribute to aviation GHG emission reductions and to the diversification of the sector's fuel supply, but achieving significant reductions will require time and a determined political will. Initiatives have to be decided in the very near-term to start the process and generate the learning and technological progress which is required to enable a more accelerated future deployment and achieve current 2050 emissions reductions targets. This will require a combination of incentive measures to overcome the initial economic barriers and foster the required technological developments.

ICAO will be an important actor in facilitating, on a global basis, the promotion and harmonization of initiatives that encourage and support the development of sustainable alternative fuels for international aviation. ■

Contributing Authors

(based on reports by the SWAFEA consortium):
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Converging Interests

At the invitation of President Dilma Rousseff, the President of the United States, Barack Obama, paid a State Visit to Brazil in March 2011.

Amongst other agreements and reaffirmations, the Heads of State agreed that the two countries have shared interests in energy-related matters, including oil, natural gas, biofuels and other renewables.

Pursuant to these developments, the *Journal* spoke recently with Guilherme Freire, Environmental Strategies and Technologies Director at Embraer S.A., concerning the implications of the new U.S./Brazil strategic partnership on energy and the implications for ongoing aviation biofuels development in the Americas.

Guilherme Freire is a Civil Engineer. He coordinates environmental issues at the Brazilian Aerospace Industry Association (AIAB), is a Board Member for the Air Transport Action Group (ATAG) and is the Executive Director of the Brazilian Alliance for Aviation Biofuels (ABRABA). Freire joined Embraer S.A. in 2002 and worked for its E-Jet Program Management Team until 2005. From 2006 through 2008, Freire began representing Embraer on matters relating to foreign affairs, trade and the environment in various governmental forums, as well as with relevant international organizations and industry associations. Since 2008 he has overseen Embraer's Environmental Strategies, developing the manufacturer's environmental protection policies while supporting its business units and other departments in establishing strategies for reducing the environmental impact of Embraer's manufactured products and production processes.

GUIDING BRAZILIAN PRIVATE/PUBLIC BIOFUELS ADVANCES THROUGH ABRABA

abraba

aliança brasileira para biocombustíveis de aviação

The Brazilian Alliance for Aviation Biofuels (Aliança Brasileira para Biocombustíveis de Aviação – ABRABA) was formed in May 2010. The group was originally comprised of ten organizations, including: Algae Biotechnology, Amyris Brazil, the Brazilian Association of Jatropha Producers (Associação Brasileira dos Produtores de Pinhão Manso – ABPPM), the Brazilian Aerospace Industry Association (Associação das Indústrias Aeroespaciais do Brasil – AIAB), Azul Brazilian Airlines, Embraer, GOL Airlines, TAM Airlines, TRIP Airlines, and the Brazilian Sugarcane Industry Association (União da Indústria da Cana-de-Açúcar – UNICA).

The objective of the alliance is to promote public and private initiatives that seek to develop and certify sustainable biofuels for aviation. The goal will be achieved through dialogues with those who form public policies, as well as opinion makers, in order to obtain biofuels that are just as safe and cost efficient as petroleum derivatives.

ICAO Journal: **What are the short-term and long-term goals for aviation biofuels in the Americas and what do you feel have been some of the more important accomplishments to date?**

Guilherme Freire: As recently as a few years ago aviation biofuels were still very much in a conceptual stage. This was true both for the Americas and for biofuels development in other regions as well. I think some outstanding progress has been made since that time, from the point where industry only had technical questions and safety questions regarding biofuels implementation to the incredible accomplishments of the past three to four years such that we now have a range of biofuel candidates undergoing both laboratory and in-situ commercial jet testing.

Today the industry at large is very close to realizing full certification of the first jet biofuel development process and we can see lots and lots of emerging technologies coming down the pipeline. The future remains bright and I would see a very long road ahead for biofuels, primarily because it's mandatory that our sector determines and implements fuel supply and affordability solutions that are truly sustainable. It's very difficult to speak about firm targets at this stage but the International Energy Agency (IEA), for instance, has established a roadmap for industry that would see 32 exajoules of biofuels employed on a global basis by 2050, providing 27 percent of total world transport fuel needs at that point. This is a huge challenge for the entire biofuel supply chain.

In your opinion, how extensive are the current levels of biofuel research and development in Brazil?

Specifically with respect to aviation, I would say we are moving very quickly. There are presently several different projects that are ongoing, at varying levels of maturity, but two especially come immediately to mind.

The first is associated with TAM Airlines, which is working closely with local jatropha producers to develop a sustainable aviation biofuels value chain. This initiative brings together key players in Brazil to on the one hand foster improved jatropha R&D with respect to scaling up its production, secondly to better understand the distribution logistics of the resulting new fuel, thirdly production capacity vis-à-vis future biofuels refineries, and fourth the completion of comprehensive jatropha fuel sustainability studies including full life-cycle analyses. The technology and fuels being developed in this regard are based on Hydrotreated Renewable Jet (HRJ), a term used to describe any feedstock or process that leads to fuel that is chemically identical to crude oil-based kerosene (see sidebar).

The second project involves Embraer, General Electric (GE) and Amyris. These three companies announced the signing in 2009 of a Memorandum of Understanding to evaluate the technical and sustainability aspects of Amyris's No Comprise® renewable jet fuel. The initiative will culminate in a demo flight in early 2012 of an Embraer E-Jet using GE engines and belonging to Azul Linhas Aéreas. This collaboration combines industry leadership in airframe and engine manufacturing, a new and committed airline, and next-generation jet fuel development and production using sugarcane as a biomass. The use of sugarcane as the main source of biomass differentiates this project from others employing the HRJ process we discussed earlier, which is oil-based. The goal is to accelerate the introduction of a renewable jet fuel that could significantly lower greenhouse gas (GHG) emissions and provide a long-term sustainable alternative to petroleum-derived jet fuel.

What degree of priority has Brazil and the Brazilian airlines specifically been giving to these initiatives?

Brazil is definitely one of the world leaders in alternative fuels and renewable energy. This is in part due to the decades of fuel self-sufficiency programmes that the State put in place after the first oil crisis in the 1970s, including the establishment of its national ethanol programme in 1975, when about 90 percent of Brazil's fuel consumption depended on foreign oil. In the decades since, Brazil has led the world in the use of alter-natives to petroleum-based fuels, most notably in sugarcane-derived ethanol.

Biofuels for aviation are rapidly emerging as one of the newer and exciting growth areas in this regard. Many new biotech companies are either coming to Brazil now or forming strategic partnerships with Brazilian firms. The Brazilian airlines, as noted earlier, are leading projects in this area and the Brazilian Alliance for Aviation Biofuels (Aliança Brasileira para Biocombustíveis de Aviação, ABRABA) is now helping to promote, facilitate and direct more coordinated progress in aviation biofuels development with a single voice, both here in Brazil and around the world.

I should add that the Brazilian Government is also closely following this process and I would say that the recently-formalized agreement on energy between Brazil and the United States is a signal of this new level of State commitment.

Let's discuss that new agreement for a moment. In it Brazil and the United States have expressed strong mutual commitments to energy-related matters, including biofuels for aviation and other renewables. Would you say that these countries represent good natural partners where the development of aviation biofuels is concerned?

I want to note from the onset that ABRABA is very supportive of this agreement and it congratulates both countries in taking leadership roles in this regard. This will speed up aviation biofuels development in Brazil and will contribute to both countries' already-established and world leading biomass production sectors across the entire value chain. The complimentary experience, resources and knowledge that can now be brought to bear from these new partners should significantly transform the rate of progress that could have otherwise been expected regarding aviation biofuels implementation.

TAM AIRLINES: PURSUING JATROPHA-BASED HRJ SOLUTIONS

Ground crew complete the fuel up of the TAM Airbus 320 in November of last year prior to its landmark flight using a jatropha curcas-based biofuel. In addition to the pilots, 18 other passengers, among them technicians and executives from TAM and Airbus, were also on the flight.

In November 2010, TAM Airlines carried out the first successful experimental flight in Latin America using aviation biofuel derived from the oil of the jatropha curcas, a Brazilian vegetable biomass. The flight employed an Airbus A320 equipped with CFM56-5B engines and was authorized by the European Aviation Safety Agency (EASA) and Brazil's National Civil Aviation Agency (Agência Nacional de Aviação Civil, ANAC). It flew over the Atlantic Ocean for 45 minutes before returning to its point of origin.

The next step in the project is to implement and establish a crop of jatropha curcas, in reduced scale, at TAM's Technological Centre in São Carlos, located in the countryside in the state of São Paulo. The production of biofuel with Brazilian raw materials results in important social and economic benefits in addition to the sustainability and emissions benefits derived from biofuels. The jatropha vegetable biomass is 100 percent Brazilian, from family agricultural projects and sizeable farms in Brazil that are dedicated to pioneering the cultivation of the Jatropha curcas. Known in Brazil as pinhão manso, jatropha does not compete with the food chain because it is not suitable for human or animal consumption and can be planted alongside pastures and food crops.

Studies conducted by the Michigan Technological University along with UOP/Honeywell have demonstrated that aviation biofuels made from jatropha curcas enable a reduction of between 65 and 80 percent in net (or lifecycle) carbon emissions in relation to petroleum-derived aviation kerosene.

Noting the interdependence among peace, security and development, this past March 2011 President Rousseff of Brazil and U.S. President Obama reaffirmed their desire to build a just and inclusive world order, which promotes democracy, human rights and social justice.

Recognizing the need of reforming international institutions to reflect the current political and economic realities, the two leaders welcomed the designation of the G20 as the premier forum for coordinating economic policy, and efforts to reform the governance of international financial institutions. They highlighted the maturity and depth of the relationship between Brazil and the United States, which is based on shared values and principles and characterized by the ties of friendship that have brought their multicultural nations closer throughout their histories as independent States.

Rousseff and Obama also decided to elevate to the Presidential level the major dialogues between the two countries, including the Global Partnership Dialogue, the Economic and Finance Dialogue, and the Strategic Energy Dialogue. The leaders directed the ministers involved to convene and report to them regularly.

The following is the environment-related portion of new Brazil/U.S. agreement that resulted from these discussions:

Energy, Environment, Climate Change and Sustainable Development

The Heads of State agreed that the two countries have converging interests in energy-related matters, including in oil, natural gas, biofuels and other renewables. President Obama stated that the United States seeks to be a Strategic Energy Partner of Brazil. They praised the Working Group on Energy and the Memorandum of Understanding to Advance the Cooperation on Biofuels and decided that their work will be carried out under the umbrella of a bilateral Strategic Energy Dialogue.

They supported the progress achieved under the Memorandum of Understanding to Advance the Cooperation on Biofuels, particularly in relation to cooperation in third countries. They welcomed the participation of the Organization of American States (OAS) and the Inter-American Development Bank in such trilateral cooperation. They underscored the importance of mobilizing public and private research institutions in the two countries to intensify cooperation in developing innovative technologies to produce advanced biofuels, and committed to enhance the bilateral and multilateral dialogue on sustainable production and use of bioenergy.

The Presidents took note, with satisfaction, of the launching, under the Memorandum of Understanding to Advance the Cooperation on Biofuels, of the Partnership for the Development of Biofuels for Aviation, which provides for coordination in establishing common standards and specifications, and strives to facilitate bilateral cooperation by convening experts from research institutions, academia, and the private sector.

They welcomed the strengthening of the collaboration on environment and climate change, including under the Common Agenda on Environment and the Memorandum of Understanding on Cooperation Regarding Climate Change, and agreed to include in the Common Agenda a discussion on the concept of green economy.

They agreed on the importance of a green economy in the context of sustainable development as a means for generating economic growth, creating decent jobs, eradicating poverty and protecting the environment. In this sense, they agreed to initiate a dialogue on a joint initiative on urban sustainability cooperation which will serve as a platform for actions addressing the challenges and opportunities of developing urban infrastructure that promotes sustainable development with concrete economic, social and environmental benefits.

They expressed their satisfaction with the conclusion, in September 2010, of the Tropical Forest Conservation Act, which provides for converting foreign debt into credits for the conservation of tropical forests.

They underscored the importance of the Energy and Climate Partnership of the Americas (ECPA) and recognized the relevance of the project "Sustainable Urban Planning and Energy Efficient Construction for Low-Income Areas of the Americas". Brazil conveyed its intention to host an ECPA Ministerial Meeting in the future.

The Heads of State reiterated their satisfaction with the Cancun agreements at the 16th Conference of the Parties of the United Nations Framework Convention on Climate Change. They affirmed their commitment to the implementation of outcomes of the Cancun Meeting and to enhance efforts in anticipation of a successful outcome in Durban, South Africa.

They reiterated the importance of the United Nations Conference on Sustainable Development (Rio+20), which will be held in Rio de Janeiro, in 2012, and committed to work closely together to ensure its success.

What are the objectives of CAAFI (Commercial Aviation Alternative Fuels Initiative) and ABRABA and how will these bodies be able to work together more effectively under the umbrella of the U.S.-Brazilian partnership?

The CAAFI/ABRABA relationship is important from the standpoint that the private sector needs to be engaged in this process. We've been conducting informal discussions with CAAFI for a long time now and have a strong relationship already in place, and now we will continue to work for all members aligned with our States in a more united energy strategy. We look forward to strengthening our outreach and communications with the CAAFI partners as well as working together on further sustainability studies and life cycle analyses.

With respect to the encouraged involvement of the OAS (Organization of American States) and third countries in these initiatives, which States do you see becoming involved with Brazil and the U.S. in aviation biofuel research and what types of contributions might they have to offer?

The development of biofuels brings direct opportunities to developing countries. Biomass production and the biofuels value chain significantly contribute to local employment through the growing of raw materials, transporting them to refineries, and production within those refineries. Furthermore, local development of biofuels and biofuels production technologies helps decrease local dependency on fossil fuels, which most Central and Latin American countries now have to import.

Brazil has partnerships being put in place or already established in developing countries in Africa and Southeast Asia that will lead to huge gains in this area for both sides.

What is the role of other private sector companies in these developments and what measures do you see being implemented at the State level to help improve private sector contributions to biofuels R&D?

We understand that the private sector, and by that I mean airlines, venture capital, energy companies, etc., will be key players in this process. There are many biotech companies that are emerging now as a result of academic research and advances and these new players will need mature private sector partners to bring their value-offerings effectively to market.

Do you see a role for ICAO in helping to coordinate some of the more multilateral initiatives that will need to support the success of the new U.S.-Brazil partnership?

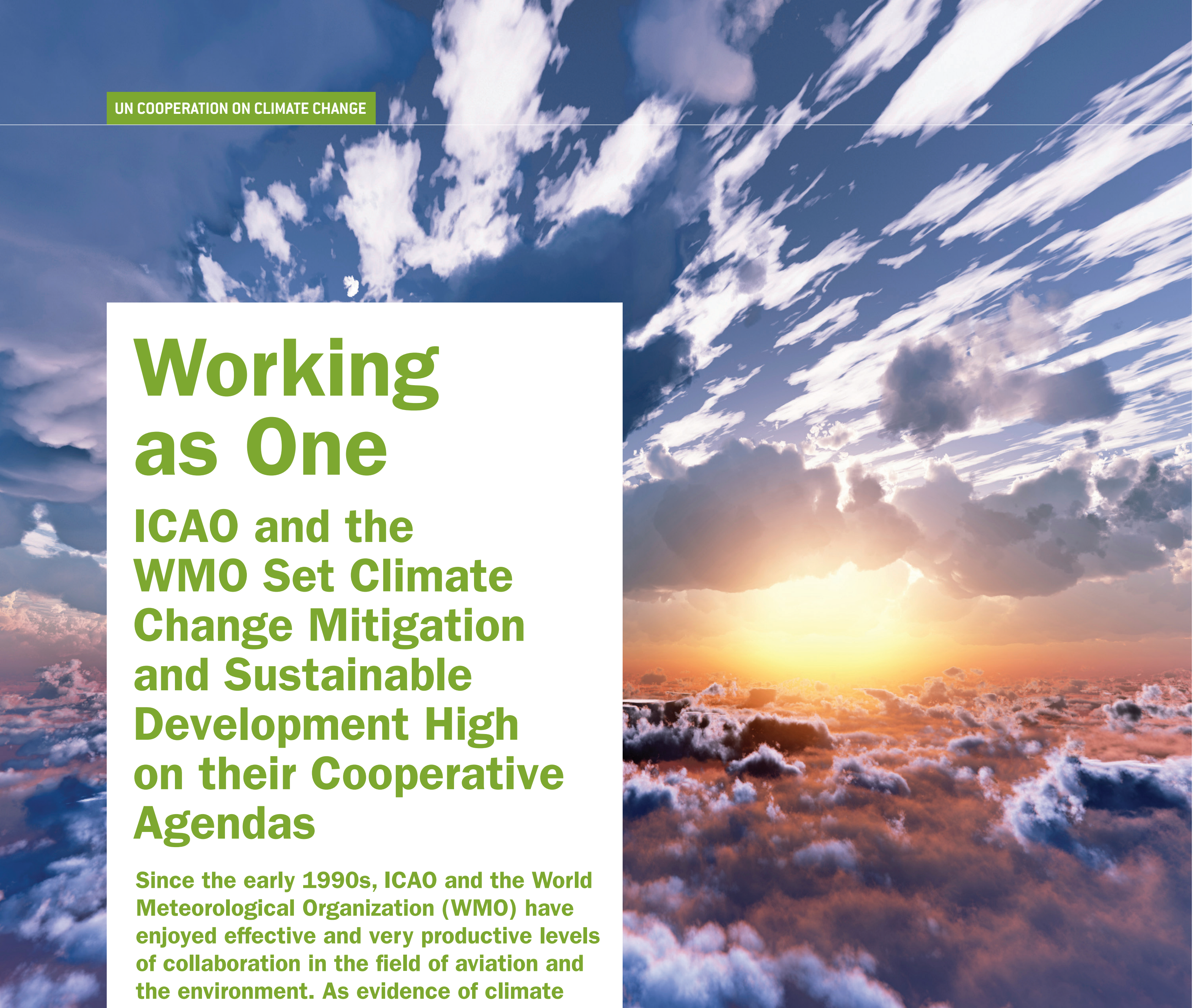
ICAO has a very important role to play. It has been engaged and very prominent over the last several years facilitating the exchange of information between its Member States and the private sector through Seminars and Workshops. The message and urgency that ICAO has been helping to communicate around the world is absolutely one of the reasons why the Brazilian Government is now making aviation biofuels development a more important priority. ■

BRAZIL'S SWEET FOUNDATION FOR BIOFUEL GROWTH

Sugarcane has been the foundation of Brazil's much-lauded energy and fuel self-sufficiency programmes, first put in place during the oil crisis of the 1970s. Ethanol production in Brazil uses sugarcane as feedstock and relies on first-generation technologies based on the use of the sucrose content of sugarcane. Ethanol yield has grown 3.77 percent per year in the country since 1975, due to improvements in the agricultural and industrial phases of related production process.

There are hundreds of ethanol plants operating in Brazil, dedicated to ethanol production alone or to producing both sugar and ethanol. Most automobiles in Brazil run either on hydrous alcohol (E100) or gasohol (E25 blend), as the mixture of 25 percent anhydrous ethanol with gasoline is mandatory in the entire country. Since 2003, dual-fuel ethanol flex vehicles that run on any proportion of hydrous ethanol and gasoline have been gaining significantly in consumer popularity.

Unlike oil-based biofuels now being developed from a variety of plants and organisms, such as corn, soybeans or green algae, sugarcane-derived biofuels are created through a process whereby the fermentable sugars in waste sugarcane cellulose, or *bagasse*, are converted for bioethanol production. New methodologies are required to achieve such an outcome, including the controlled, high level expression of cellulases in transgenic sugarcane and processing technologies that enable the cost-effective use of these enzymes to convert bagasse to fermentable sugars. One study (Stanford, 2008) has shown that large-scale microbial systems could be used to convert the exposed cellulose into fermentable glucose sugars more sustainably than existing biofuel processes.



Working as One

ICAO and the WMO Set Climate Change Mitigation and Sustainable Development High on their Cooperative Agendas

Since the early 1990s, ICAO and the World Meteorological Organization (WMO) have enjoyed effective and very productive levels of collaboration in the field of aviation and the environment. As evidence of climate change became ever more apparent during that decade, the value of this cooperation was further highlighted in documents such as the *Special Report on Aviation and the Global Atmosphere,* which was prepared at ICAO's request by the UN Intergovernmental Panel on Climate Change (IPCC).

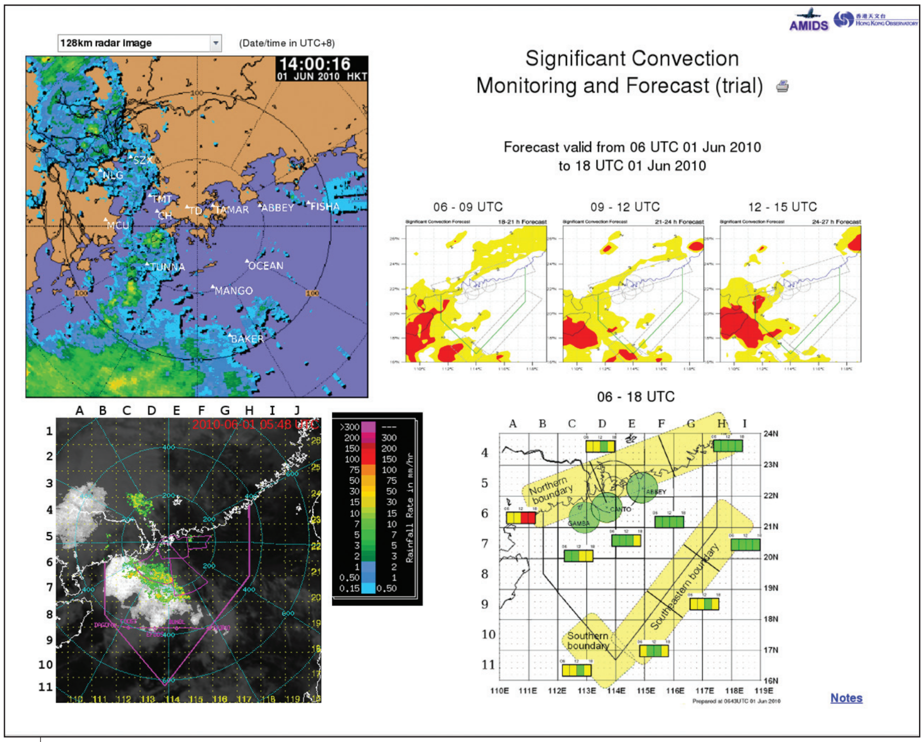
As Dr. Herbert Pümpel reports, ICAO and the WMO continue today to cooperate on a range of climate and environmental concerns, providing researchers with invaluable data and contributing significantly to our current and more comprehensive understanding of climate change impacts.

Dr. Herbert Pümpel has served as WMO Chief, Aeronautical Meteorology Division, since 2006. He also is the Acting Director of the WMO's Meteorological Applications Branch and has been Officer-in-charge of the organization's Quality Management Framework since 2008. Pümpel served as a Senior Analyst in the Operations Department of the European Centre for Medium Range Weather Forecasts (UK) from 1978 to 1985. He has been a Member of the WMO Commission for Aeronautical Meteorology since 1990, holding several positions as Chair of OPAGS and Expert Teams. He also acts as the WMO representative to the ICAO Committee on Aviation Environmental Protection (CAEP)—a position he has held since 2000. Pümpel was head of western region, Austrocontrol Aviation Met Service, from 1991 to 2005, served as Center Director for the Mesoscale Alpine Programme from 1998-1999, was a lecturer in Aviation Meteorology, University of Innsbruck from 2001 to 2006, and served as CEO of Meteoserve, the commercial branch of the Austrocontrol Aviation Met Service, during 2005–2006.

For many years, the World Meteorological Organization (WMO) has been actively involved with ICAO's Committee on Aviation Environmental Protection (CAEP). Excellent cooperation has characterized the relationship between ICAO's ENV and the WMO's Aeronautical Meteorology divisions. Issues of aviation's effect on the environment mostly have an atmospheric component, for which the WMO has provided expertise and advice over the years. In particular, when it comes to climate change, aeronautical meteorology has been fully engaged in supporting efforts regarding operational measures to reduce fuel burn and thus emissions.

In recent years, research efforts have gotten underway to improve the quantification of the complex radiative effects of aviation-induced persistent contrails and cirrus clouds, for which work on possible mitigating action has also begun. While few sectors over the past 60 years have been able to compare to aviation with respect to improving the energy efficiency of their operations, the continuing growth global air transport requires continued and committed effort by scientific, technological and operational stakeholders to mitigate the rise in emissions that will otherwise inevitably accompany the increasing numbers of aircraft in our skies.

Special efforts are presently underway in the WMO and ICAO to foster improved access to, and use of, dedicated forecasts for ATM with a focus on the wider terminal area. A dedicated WMO Expert Team on new Meteorological Services for the Terminal Area is currently coordinating several global efforts to improve the use of weather information in ATM with a view to further reducing unnecessary fuel burn by optimizing flight operations.



Some of the results from the April 2011 Significant Convection Monitoring and Forecast tests by the Hong Kong Area Control Centre. These tests covered the entire Hong Kong FIR. The six-to-twelve hour convection forecasts were based mainly on NWP products, Radar, Lightning Detection and Nowcasting. Images courtesy of the Hong Kong Observatory, Hong Kong, China.

Partners in Environmental Monitoring

While data from meteorological satellites provides invaluable information on many atmospheric parameters on a global scale, detailed information of the vertical structure of the atmosphere (which in turn determines such processes as air quality near the ground, convective storms and wind shear, as well as turbulence) and very accurate in-situ measurements of temperature, moisture and wind are still required for a more comprehensive snapshot of climate-related conditions.

Historically, the only observing system capable of providing such detailed, in-situ atmospheric measurements were *radiosondes*—specialized units used in weather balloons to measure various atmospheric parameters and transmit them to a fixed receiver. These are to be distinguished from *dropsondes*, which are radiosondes deployed by being dropped from an aircraft instead of being carried aloft by a balloon.

Once radiosondes reach a certain altitude their weather balloons burst due to atmospheric pressure and the units are lost and must be replaced for the next set of measurements required. Although radiosondes results are highly accurate and detailed, their significant replacement and staff support costs limits the number and frequency of affordable observations—particularly in the developing world.

As an alternative to the radiosondes method, a global programme to make the temperature and wind observations taken by commercial aircraft available via downlink to the meteorological community was originally launched in 1978 and was later revived in the late 1980s. This collaborative approach between weather and aviation stakeholders has now become a vital part of the global atmospheric observing system, with approximately 250,000 observations per day typically being made available via this method to scientists and researchers.

These aircraft observations, apart from providing invaluable information for the improved analysis and forecast of winds and temperatures (which in turn support the mitigation of carbon emissions as mentioned in the introduction), greatly help researchers to better understand smaller scales of motion in the free atmosphere. The current introduction of additional sensors into in-service aircraft to gauge atmospheric humidity will also substantially increase our collective scientific and climactic understanding of convective processes, cloud formation and (as a consequence) radiative effects.

Climate change also strongly depends on the presence of different aerosols, i.e. solid and liquid particles carried by the atmosphere which influence its radiative properties. Again, excellent cooperation between the meteorological community and the airline industry under WMO and ICAO auspices has, for many years, provided invaluable data that contributes to a better understanding of weather and climate.

These measurements require large and dedicated instrumentation that must be carried by commercial aircraft. The goodwill of aircraft operators is therefore fundamental to the success of this research. Some international meteorological research projects involving in-service aircraft, such as MOZAIC, IAGOS-ERI and CARIBIC, to name but a few, have become milestone achievements in the field of atmospheric chemistry and have significantly contributed to the influence research in this area provides on climate change and variability *(see sidebar on page 35)*.

The presence of volcanic ash in the atmosphere following major volcanic eruptions is another significant atmospheric occurrence which benefits from increased cooperation between aviation and meteorological researchers. Eruptions not only affect the climate (by dimming radiation and thus leading to short-and medium term cooling of the earth's atmosphere), but volcanic ash also constitutes a serious risk to aircraft engines and other internal and external aircraft components. Coordinated efforts in the field of volcanic ash observations, forecasts and warnings, have been further reinforced in the aftermath of the European volcanic ash crisis following the eruption of Eyjafjallajökull in Iceland in April 2010.

Climate Variability and its Influence on Civil Aviation

In 2007, the WMO first raised the issue of possible effects due to climate change on aviation at an ICAO environmental conference in Montreal, organized by the Organization's Environment Branch in cooperation with the CAEP. This drew on the industry's attention to the risk potential of already-occurring and expected aspects of climate change on the aviation sector; effects which are broadly divided into three main areas:

1. The effects of changing weather patterns and the intensity and frequency of hazardous weather phenomena impacting aviation operations. This would include the severity and frequency of convective storms, the height of their cloud tops affecting international airways, or the likelihood of intense snowfall and protracted wintery conditions.

2. The long-term effects of climate change for route planning and aviation infrastructure projections. Here changes in the seasonal position of the jet stream could be of interest for route planners, while airport planners would need to begin to take account of the increased risks associated with heavy precipitation or, in case of coastal airports, storm surges.

3. The potential influence of climate change on the economic environment aviation operates in. This could include changes in demand, economic viability and the validity of existing business models. Desertification of popular holiday destinations, lack of snow for winter sport destinations, coastal erosion as a consequence of sea level change, as well as numerous other potential climate change impacts could influence both planning horizons and investment decisions for tourism and consequently air transport stakeholders.

INTERNATIONAL METEOROLOGICAL RESEARCH PROJECTS INVOLVING IN-SERVICE AIRCRAFT

The use of in-service aircraft for in-situ measurements of the atmospheric conditions has a long tradition, beginning in the 1970s when NASA implemented its Global Atmospheric Sampling Program. The following are some of the more significant collaborative research initiatives involving meteorological stakeholders employing in-service aircraft to assist with comprehensive atmospheric observation and reporting. To date this cooperative effort between meteorologists and aircraft operators has been highly instrumental in improving our understanding of atmospheric chemistry and climate change.

MOZAIC

MOZAIC was initiated in 1993 by European scientists, aircraft manufacturers and airlines to better understand the natural variability of the chemical composition of the atmosphere and how it is changing under the influence of human activity—with particular interest on the effects of aircraft. MOZAIC consists of automatic and regular measurements of reactive gases by five long range passenger aircraft. A large database of measurements (about 30,000 flights since 1994) allows for studies of chemical and physical processes in the atmosphere, validations of global chemistry transport models and satellite retrievals.

MOZAIC data provided detailed climatological metrics of trace gases at 9-12km, where subsonic aircraft emit most of their exhaust and a very critical domain (e.g. radiatively and with respect to stratosphere-troposphere exchanges) still imperfectly described in existing models. MOZAIC data also provided frequent vertical profiles over a large number of airports, including Frankfurt, Paris, Vienna, New York, Atlanta, Tokyo, Beijing, Sao Paulo, Johannesburg, and others.

MOZAIC was evolved in 2004 into the European Research Infrastructure IAGOS (In-service Aircraft for a Global Observing System) initiatives that are described below.

CARIBIC

CARIBIC stands for *Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container.* This programme took a different approach by deploying an instrumented cargo container aboard an LTU Boeing 767 and later a Lufthansa A340-600 on a monthly basis. The large set of measurements provided through the CARIBIC programme comprises those mentioned as well as hydrocarbons, halocarbons, and isotopic composition. A sophisticated inlet system allows accurate measurements of aerosols and allows remote sensing by differential absorption spectroscopy.

IAGOS ERI

IAGOS-ERI is a distributed infrastructure programme for observations of atmospheric composition, aerosols, clouds and contrails on the global scale from commercial in-service aircraft. For this purpose, new instrument packages were developed based on the former MOZAIC instrumentation for O_3, H_2O, CO and NOy/NOx.

IAGOS-ERI was initiated by FZJ, CNRS, Meteo France, and Airbus, together with a growing community of research institutions and airlines. The programme deploys newly developed high-tech instruments for regular in-situ measurements of atmospheric chemical species, aerosols and cloud particles. This data is available in near real time to weather services and GMES service centres. IAGOS-ERI provides a database for users in science and policy, including near realtime data provision for weather prediction and air quality forecasting. It will provide data for climate models, including those used in the GMES Atmospheric Service, and the carbon cycle models used for the verification of CO_2 emissions and Kyoto monitoring.

In 2009, the WMO convened the third World Climate Conference as a high-level platform for climate scientists, societal decision makers and representatives of countries from different regions and different stages of development to discuss the likely effects of climate change on varying societal sectors. The event also looked into the possible ways that improved climate observation, science and services could help these affected groups and sectors to adapt to and mitigate the effects of climate change.

The Conference accordingly decided in its High-level Segment to establish a Global Framework for Climate Services (GFCS).

A High-level Taskforce was put in place with the responsibility to provide a report on the societal needs, governance structure and funding basis for future services in this regard. This report will have been presented to the Secretary General of the United Nations early in 2011.

It may be useful to consider some of the relevant findings of this highly interesting report in the fields of aviation and climate change. The following speaks to the points just touched upon regarding the interrelatedness of many economic sectors and their common interdependence on a stable climate:

> *"Good policy and planning depends on good evidence and information. Climate information is critical for major decisions concerning, for example, new water supply reservoirs, plans and infrastructure for expanding settlements and sectoral economic policy targeting climate-sensitive industries, e.g., tourism, renewable energy or aquaculture."*

The science of climate prediction also relies heavily on global circulation models of the combined Atmosphere-Ocean system. On the predictability of short variations, the report concludes:

> *"While global climate models have sufficient spatial resolution to represent global and continental scale phenomena successfully, they are less able to represent phenomena on the smaller national and sub-national scales that are often of greatest interest to decision makers, such as local patterns of temperature and precipitation extremes. Higher model resolution in space and time can potentially provide some improvement in resolving smaller scale features but comes at a high cost and so resolution is expected to improve only gradually."*

While the need for climate services can now be assumed to be at least generally understood, it is very important to develop realistic attitudes towards the achievable reliability of related information and the basic, inherent uncertainty of any atmospheric forecast. In dealing with this uncertainty, the report recommends:

> *"Despite advances in our ability to predict the weather and climate, all predictions on a range of different timescales have some measure of uncertainty. Climate services will need to provide reliable estimates of the uncertainty of predictions to allow users to manage their own risks in an objective way. Characterizing and communicating uncertainty is fundamental for decision-making. Underestimating uncertainty can lead to excessive responses that are inconsistent with decision makers' risk tolerance and can damage the credibility of the service provider. Overestimating uncertainty leads to lost opportunities for preparing for adverse conditions or for capitalizing on favourable conditions."*

It is expected that the implementation of the GFCS will lead to the establishment of a User Interface Platform designed to bring climate service users and providers together. It should additionally promote a more effective level of dialogue that will lead to a highly responsive climate service delivery capability.

It is my hope that ICAO can find a way to interact with this platform so that the needs of the aviation sector are well understood by those charged with implementing the underlying system support—research, observations and information systems that will be crucial components of the GFCS.

In closing, I would strongly recommend to apply the time-honoured division of responsibilities between ICAO and WMO to the new field of climate services. ICAO, with its access to and understanding of the aviation sector, will be needed to develop specific requirements for climate services in close cooperation with user representatives and the WMO, representing the service provider community. Considering the highly successful levels of cooperation achieved between these two UN Organizations in the past, I am confident that highly satisfactory and sustainable service delivery arrangements and requirements will be developed. ■

ICAO SUPPORT FOR IPCC

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socioeconomic impacts.

ICAO cooperates with IPCC on improving methodologies used when calculating aviation emissions and quantifying their impacts. The production of the IPCC 1999 special report on "Aviation and the Global Atmosphere" and a more recent IPCC assessment published in 2007, the IPCC Fourth Assessment Report (AR4), are outstanding examples of such cooperation.

The IPCC has initiated the preparation of its Fifth Assessment Report (AR5), which is scheduled to be completed in 2014 and ICAO is participating in the IPCC process to ensure that issues related to aviation and climate change are covered appropriately.