A Summary of Research and Perspectives Presented at The ICAO Workshop on Aviation and Alternative Fuels

(Montréal, 10-12 February 2009)

Compiled by the ICAO Environment Section

PREFACE

The International Civil Aviation Organization (ICAO) develops a range of Standards, policies and guidance material for the application of integrated measures to address aircraft noise and engine emissions. To enlarge its knowledge base and bring new facets to its work in minimizing the environmental impact of aviation, ICAO regularly organizes workshops to seek further advice on new and emerging issues, such as the impact of alternative fuels on the sustainability of future industry growth by their potential to reduce its emissions footprint.

The ICAO Workshop on Aviation and Alternative Fuels is a good example of how ICAO places at everyone's disposal, the benefit of the best available expertise in order to support data-based decision making for global aviation. The results of this workshop have provided critical input to ICAO and will allow consideration of sound policy options in this field.

This summary of the workshop identifies common threads and messages emerging from the wide range of presentations at the meeting; and shapes them into a framework that has proven useful in the past when considering global environmental policy issues. It covers the four strategic areas of environmental benefits, technological feasibility, economic reasonableness, and interdependencies with other environmental factors. It also captures proposed actions and areas requiring further inquiry which, combined with the critical mass of information contained in the presentations themselves, form the basis for the agenda of a global alternative fuels conference planned for November 2009. The main objective of the Conference is to facilitate international coordination of roadmaps for enabling the deployment of aviation alternative fuels.

The information contained in this document should therefore be of interest to all members of the aviation community, including energy producers, airlines, airports and equipment manufacturers, as well as policy-makers at regional, national, and local levels, who play a role in the decision-making process related to energy and environmental policy with respect to air transport.

INTRODUCTION

Despite its relatively small contribution to worldwide greenhouse gas emissions, the civil aviation community fully acknowledges its responsibility to limit and reduce emissions, including those that contribute to global warming, and to promote energy security and independence. It is particularly important given the projected growth of the aviation industry in the coming decades and its limited options compared with other transport sectors, to divert from the use of fossil fuels. A variety of emission reduction approaches, including the deployment of alternative fuels, are being seriously considered towards that end.

The proactive approach relating to alternative fuels was emphasized by the 36th Session of the ICAO Assembly (A36) held in September 2007. At this Session, the Organization's sovereign body "recognized the importance of research and development in fuel efficiency and alternative fuels for aviation that will enable international air transport operations with a lower environmental impact". The Assembly further "encouraged the [ICAO] Council to promote improved understanding of the potential use, and the related emissions impacts, of alternative aviation fuels".

Accordingly, ICAO's Committee on Aviation Environmental Protection (CAEP) promptly undertook efforts to "promote improved understanding of the potential use and emission effects of alternative fuels". This initiative also responded to a related request from the ICAO Council and the Group on International Aviation and Climate Change (GIACC) for information on technological advances, including alternative fuels, for reducing air transport's carbon footprint. The GIACC was created following A36 and is composed of senior government officials. Its mandate is to recommend an aggressive ICAO programme of action on international aviation and climate change.

It was thus in support of the requests from the ICAO Council, GIACC and CAEP, that the Environment Section of the Air Transport Bureau of ICAO organized the Workshop on Aviation and Alternative Fuels, with two primary objectives: to stimulate a dynamic exchange of views and to initiate work on a global roadmap for the effective and responsible contribution of aviation alternative fuels to protecting the environment. The intent was for such a roadmap to constitute an integral element of ICAO's programme of action on international aviation emissions.

THE ENVIRONMENTAL CONTEXT FOR AVIATION ALTERNATIVE FUELS

In his opening address to the workshop, ICAO Secretary General Dr. Taïeb Chérif stressed the fact that reducing the use of fossil fuels should be considered as a "pressing issue". He underscored that while alternative fuels alone would not be the solution, they should be part of a comprehensive energy strategy. The decision to use them must be informed and must take into account their full life-cycle and carbon footprint. He also emphasized the need for standardization and global coordination, indicating that ICAO was committed to exercising leadership among all aviation stakeholders. He highlighted the Organization's long-standing relationship with the Intergovernmental Panel on Climate Change and the United Nations Framework Convention on Climate Change (UNFCCC), while expressing the desire to forge partnerships with the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA).

The keynote address of the workshop was delivered by Mr. Lewis Fulton, Senior Transport Energy Specialist at the IEA. Mr. Fulton provided a detailed outlook of world energy requirements and an overview of aviation's stake in the global energy challenges. World energy demand, he said, would expand by 45 percent between now and 2030 – an average rate of increase of 1.6 percent per year – with around three-quarters of the projected increase in demand for oil coming from the transportation sector. Current oil supplies, he noted, would not be sufficient to meet demand. An estimated 64 million barrels per day (mb/day) of gross capacity would have to be made available between 2007 and 2030 – six times the current production capacity of Saudi Arabia.

On the subject of greenhouse gas (GHG) emissions reductions, Mr. Fulton indicated that technological advances across all industry sectors were necessary, but that efficiency gains and deployment of existing low-carbon energy sources would account for most of the savings. IEA considered that in the long-term, in order to bring global GHG emissions back to current levels by 2050, technology options with a cost up to US$50 per tonne of Carbon Dioxide (CO_2) reduced would be needed. Furthermore, reducing GHG emissions on a global level by 50 percent when compared with today's levels would require options with a cost of US$200 to US$500 per tonne of CO_2 reduced.

IEA's forecast predicted that biofuels might contribute up to 12 percent of the total liquid fuel share by 2030, and would be based mostly on second generation non-petroleum derived fuels. This share was expected to increase to 26 percent by 2050, marking a twenty-fold increase compared to 2007. With these new sources of fuel, the question would become that of which energy consumer would they best serve. By 2050, aviation was expected to be utilising 30 percent biofuels, derived from biomass to liquid (BTL), and hydrotreated oils, and other pathways.

It was pointed out that alternative fuels derived from coal or natural gas (Coal to Liquid (CTL) and Gas to Liquid (GTL) were certainly suitable for aviation and could provide energy security benefits. However, in their current forms, they were not low CO_2 fuels as shown in **Figure 1**. On the other hand, the CTL and GTL economics were currently better than for biofuels. Additionally, current commercial biofuels such as fatty acid methyl ester (FAME) fuels derived from bio oils and fats or ethanol, were not very attractive as a "drop in" bio-jet fuel because of compatibility issues and high cost.

Mr. Fulton further indicated that BTL fuels produced using the Fischer-Tropsch (F-T) process had the potential to offer a very low CO_2 fuel for aviation, but at present, the economics looked rather difficult. The technology was not fully ready and no large-scale BTL plant existed in the world yet. In addition, harvesting biomass remained a major challenge while land-use change impacts on CO_2 were a major question. On the other hand, "third generation" biofuels, such as those derived from algae, were not affected by the land-use changes other feedstock must account for. Furthermore, algae consumed enormous amounts of CO_2 in its growth process. Algae-derived jet fuel was, in fact, recently tested in a commercial flight in the US, proving it to be an effective replacement for traditional petroleum-based fuels. While new economic and scaling challenges existed, they were no greater than those faced by other advanced biofuels.

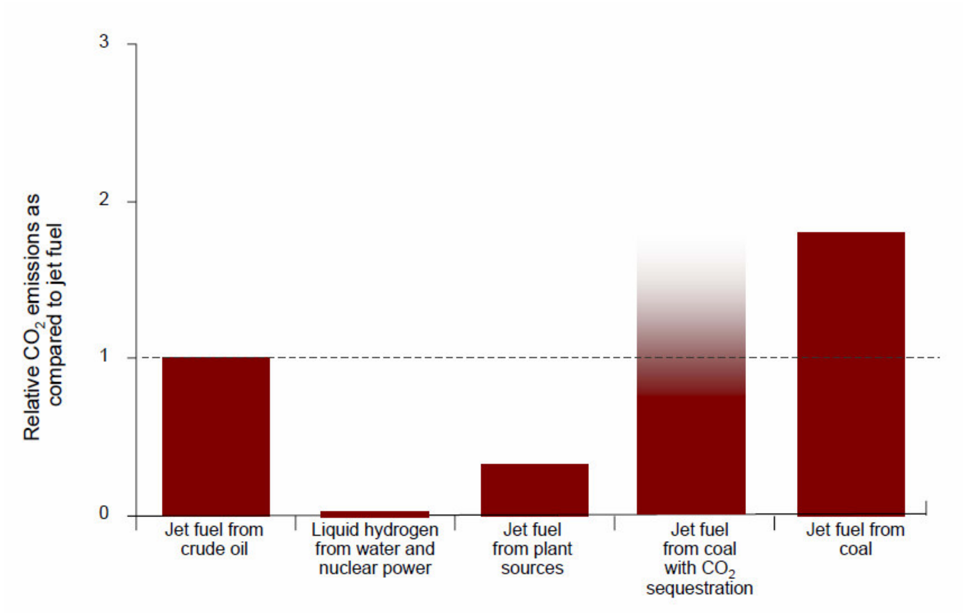


Figure 1. Lifecycle greenhouse gas emissions by fuel type: snapshot of existing technologies. Credit: The Boeing Company.

IEA concluded that current energy trends were unsustainable, both environmentally and economically. Although oil would remain the leading transport energy source, Mr. Fulton expressed the opinion that the era of low-cost oil would soon be over, though price volatility would remain. In order to avoid "abrupt and irreversible" climate change, a major 'decarbonisation' of the world's energy system was needed. Limiting the rise in temperature to 2°C, regarded by the IPCC as a critical level, would require significant GHG emissions reductions in all sectors and regions. While new aviation fuels could play an important role, only - certain fuels would deliver large reductions of CO_2.

Several other presenters including Jennifer Holmgren from UOP, Leah Rahney from Continental and Yasunori Abe from Japan Airlines, described the feasibility of second generation aviation jet fuels that involved Hydrotreated Renewable Jet (HRJ) fuel. This fuel was said to be undergoing tests by members of the aviation industry including Boeing, Continental Airlines, Japan Airlines, Air New Zealand, Rolls Royce, Pratt & Whitney, GE and CFM. Data from the tests (laboratory and field) confirmed that the fuel could be used as a "drop-in" fuel when used with petroleum in blends up to 50 percent. This industry group was putting together a report for ASTM to enable certification of HRJs as a commercial aviation fuel within the next 18 months. It was explained that HRJ technology had a significant advantage over CTL, GTL or BTL in that the capital cost (and capital risk) was similar to that of biofuel plants. Current capital cost premiums of CTL, GTL and BTL technologies were much higher than those of HRJ plants and/or involved very large capital investments (and risks). This made CTL, GTL and BTL projects difficult to finance in the current market environment.

The issue with HRJ was that of identifying a suitable source of vegetable oil that was both sustainable and could be produced at a cost that was feasible relative to the projected cost for petroleum-based fuels (excluding some premium in consideration of its carbon reduction value). Several options were being investigated in conjunction with airline field tests including Camelina, algae, waste vegetable oil and Babaçu oil. If the airlines could define and implement supply agreements that could specify this oil in quantities needed for jet fuel and with a good sustainability footprint at a price that was economic, then HRJ might become a leading contender in supply of low carbon jet fuel in the future.

In her presentation of ICAO's role and activities in aviation alternative fuels, Ms. Jane Hupe, Chief of ICAO's Environment Section, suggested that the discussions on aviation alternative fuels should focus on environmental benefits, economic reasonableness, technological feasibility, and alignment with other environmental considerations. Goals in this respect should be coordinated, realistic and achievable as well as cast within a stable predictable international framework. She also highlighted the importance of safety in aviation as the first priority in the drive for new energy sources.

Ms. Hupe reiterated the fact that ICAO could effectively galvanize stakeholders involved with aviation alternative fuels by promoting international cooperation around consistency and standardization. As the only official international forum for dealing with issues relating to international civil aviation, ICAO was committed to globally coordinating action by tapping the resources, experience and expertise that parties could bring to the table.

TYPES OF AVIATION ALTERNATIVE FUELS CONSIDERED

Various speakers presented a broad range of possibilities, varying from "drop-in" solutions available in the near term, to early research on more exotic alternatives in the distant future. It was noted that in some cases, the motivation for pursuing alternative fuels was not so much for the environmental benefits, but rather ensuring security of supply. As a result, the fuel options highlighted showed different lifecycle CO_2 properties, feedstock cost, near term feasibility, land use change impacts and co-product food values.

Mr. Philippe Fonta, Head of Sustainable Development, Airbus, provided an overview of the pathways that were currently available for producing jet fuel, indicating those that were best suited for the purpose. Although fuels such as ethanol, liquefied natural gas and hydrogen were known to exist, these were found to be more appropriate for other applications.

The chart in **Figure 2** summarizes the available means of developing jet fuel.

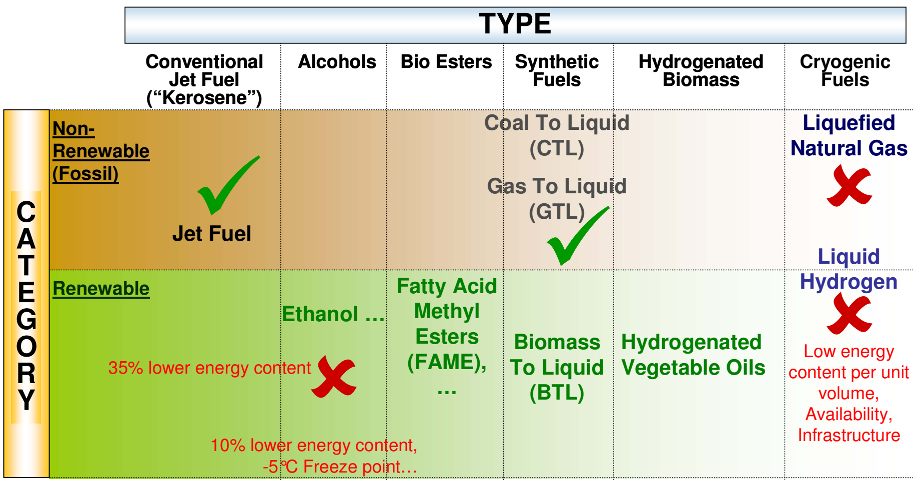


Figure 2. Commercial aviation alternative fuel options. Credit: Airbus.

Mr. Piet Roets, manager of the SASOL Fuels Research Group, explained that SASOL produced a synthetic jet fuel that was created using a coal-to-liquid process, out of a need to provide an adequate supply of jet fuel to South Africa. Ms. Jennifer Holmgren of UOP informed that the oils described in **Figure 3** were being evaluated or considered by the airlines for use in HRJ processes.

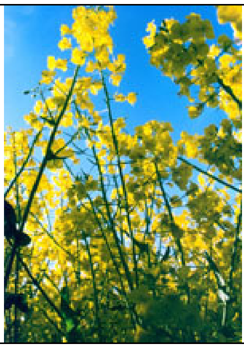
Now: Camelina	**Now: Moringa**
	
• Can be grown in rotation with wheat and increase yields • Low fertilizer, pesticide or herbicide use and low crop cost • Good carbon footprint due to low fertilizer use	• Drought tolerant, can grow on marginal land • Yield results in good economics (2 tons/ha) • Co-production of food between trees • Leaf by-product and meal highly nutritional
Now: Babacu:	**Now: Macauba**
	
• Large inventory of existing trees (15 M ha) • Co-product is biomass (substitute for coal) • Oil yield low so need market for co-products	• High yield of oil/hectare (4 tons/ha) • Co-production of food between trees • Low production cost (US$300/ton) • Edible meal for animal use

Figure 3. Sources of oil that are currently being evaluated to supply HRJ fuel. Credit: UOP.

Mr. Richard Altman, Executive Director of the Commercial Aviation Alternative Fuels Initiative (CAAFI), pointed out that in the near term, the focus was to certify fuels that could be used as "drop-in" replacements for Jet A. **Figure 4** highlights examples of feedstock options for hydrotreated renewable jet fuel. Inedible oils, such as those from the Jatropha plant, represented the end of the first generation of feed stocks that leveraged research dating back to the 1920s, while fuels derived from Jatropha and similar plants had been produced and used in test flights.

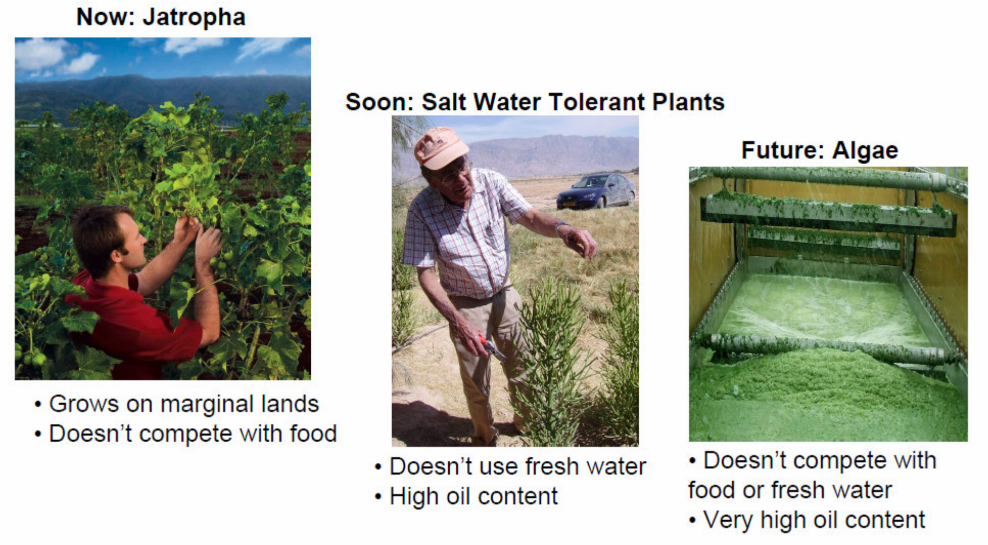


Figure 4. Sources of alternative fuel feedstock that could be used within 10 years. Credit: The Boeing Company.

Dr. Lourdes Maurice, Acting Director of the US Federal Aviation Administration's Office of Environment and Energy, informed that the technology to produce Jatropha-based fuels in quantity could be ready in two to four years. Algal fuels derived from halophytes grown in salt water and non-arable land, which offered significantly greater yields than nearer-term options, could also be available within that time frame. While some claim that it would take eight to ten years to produce fuels from algae, at least one company had already tested and proved that its algal jet fuel did in fact work, and anticipated commercial production in the three to five year time frame.

Dr. Fayette Collier, Principal Investigator of the US National Aeronautics and Space Administration (NASA) subsonic fixed wing project, discussed new methods that might be available for powering subsonic passenger aircraft in 20 to 25 years. Examples provided included liquid hydrogen, liquid methane, nuclear power and fuel cells. Each of these options would have to overcome a number of challenges including the design and production of new airframe and power plants, before it could be considered commercially viable.

Mr. Bill Wason of BioPure Fuels detailed a set of oil seed crops that had either been tested by airlines (Camelina, Babacu, Jatropha) or might be suitable as crops in considering airline sustainability issues (Macauba, Moringa). The presentation listed a set of feedstock projects under development, that would provide large volumes of these feedstocks in a sustainable manner. These included a crush project in Canada that would be able to access up to one million tons of Camelina oil seed in Saskatchewan, Montana and N. Dakota coming on line in 2011, and oil seed tree planting projects on 2.8 million hectares of state land in Maranhao, Brazil. The comparison of different crops focused on defining how to reach production costs that would be competitive while also meeting low life cycle carbon numbers needed to allow airlines to meet carbon reduction goals. Camelina was seen as a good solution because of its effect on increasing wheat yields in dry land areas where wheat is typically mono-cultured. Also of great interest were oil seed trees that could meet high yield targets, could grow in areas now highly underutilized (e.g. intensity of agriculture on land in Brazil being very low and naturally excluding any land in Amazon region) while doing this in such a way that both food and fuel goals could be achieved optimally. The planting program being developed in pilot projects would plant Macauba and Moringa oil seed trees in conjunction with food crops that fixed nitrogen. This would lead to dual crops and limited need for nitrogen fertilizer, the primary factor affecting life cycle carbon benefits of oil seed based biofuels. The conclusion was that a large quantity of oil could be produced on agricultural land that was not being used and that the planting of one million hectares of this land would result in four million metric tons of oil for HRJ at an oil production cost of about US$300/ton (representing about 85 percent of HRJ production cost).

Mr. Wason also noted that the other opportunity involved conversion of agricultural waste, particularly bagasse, into jet fuel. This would probably involve initial conversion into biogasoline and mixed alcohol and then applications in bio-refineries to convert intermediate liquids (pyrolysis oil, carboxylic acid, and ketones) to a refined jet fuel. The development of this capacity would most likely involve a joint program with new refinery construction such as the five refinery projects underway in Brazil. These new refineries would also provide the opportunity to sequester CO_2 from the refinery into algae and then convert the algae biomass into either biofuels or bio-chemicals. These bio-chemicals could be used to make bio-plastics for auto parts thus offering the potential to further lower CO_2 emissions in refining of petroleum jet fuel.

CERTIFICATION

The certification of new fuels for aviation was shown to require a substantial effort from all segments, including fuel producers, aircraft and engine manufacturers, and the users. Mr. Roets of SASOL explained the steps required to obtain certification of a Coal-to-Liquid based synthetic fuel. This offered an important example, since there was no precedent for certifying a synthetic fuel for aviation. Dr. Ravin Appadoo of Aviation Fuel Solutions explained that, as is the case with the certification of a traditional petroleum-derived jet fuel, both technical and safety aspects were considered when certifying alternative fuels.

A number of other presentations described certification related activities that were underway, indicating that some of the activities most visible to the public were the flight tests which were becoming more frequent. (**Figure 5** lists the recent flight tests using alternative fuels). Mr. Altman of CAAFI expected that as a result of these tests, a 50 percent Fischer-Tropsch blend would be certified in mid-2009.

Alternative Fuel Flight Tests

- **GE / Boeing / Virgin Atlantic - 1Q 2008**
  - **Boeing 747 using a mix of Coconut oil and Babassu oil**
- **Rolls Royce / Airbus / Shell - 1Q 2008**
  - **Airbus A380 using Gas to Liquid (GTL) derived fuel**
- **Rolls Royce / Boeing / Air New Zealand - 4Q 2008**
  - **Boeing 747 using Jatropha oil**
- **CFM / Boeing / Honeywell / Continental – 1Q 2009**
  - **Boeing 737 using Jatropha and algal oil**
- **Pratt and Whitney / Boeing / JAL - 1Q 2009**
  - **Boeing 747 using Camelina, Jatropha, and algal oils**

Figure 5. Alternative fuel flight tests to date.

The following **Figure 6** shows a possible timeline for alternative fuel certification based on the presentations during the workshop.

Today	►	100 percent synthetic coal-to-liquid jet fuel certified
mid-2009	►	50 percent Fischer-Tropsch synthetic jet fuel blends from biomass, coal, and gas certification expected
2010	►	50 percent hydrotreated renewable synthetic jet fuel blends, such as algae, certification expected
	►	100 percent Fischer-Tropsch synthetic jet fuel certification expected
	►	100 percent synthetic gas-to-liquid jet fuel certification expected
. . .		
2013	►	100 percent hydrotreated renewable synthetic jet fuel certification expected
. . .		

Figure 6. Alternative Fuel Certification Timeline

CHALLENGES

While the workshop made it clear that tremendous work was underway to develop alternative fuels for aviation, it should be noted that additional work remains before these fuels will be globally available. In this regard, Mr. Bogers of Shell highlighted during his presentation, a number of challenges that the sector would need to overcome before large-scale use of alternative fuels would become a reality. It was stressed that these challenges, in both the economic and technical domains, existed throughout the entire supply chain, from production until the fuel was consumed.

As summarized in **Figure 7**, questions remain regarding the availability of sufficient feedstock, the cost, and location of future processing facilities. Mr. Bogers noted during his presentation that, no alternative jet fuel production plants had yet been committed. However, in each of the presentations where challenges were recognized, none of the presenters felt that the challenges were insurmountable.

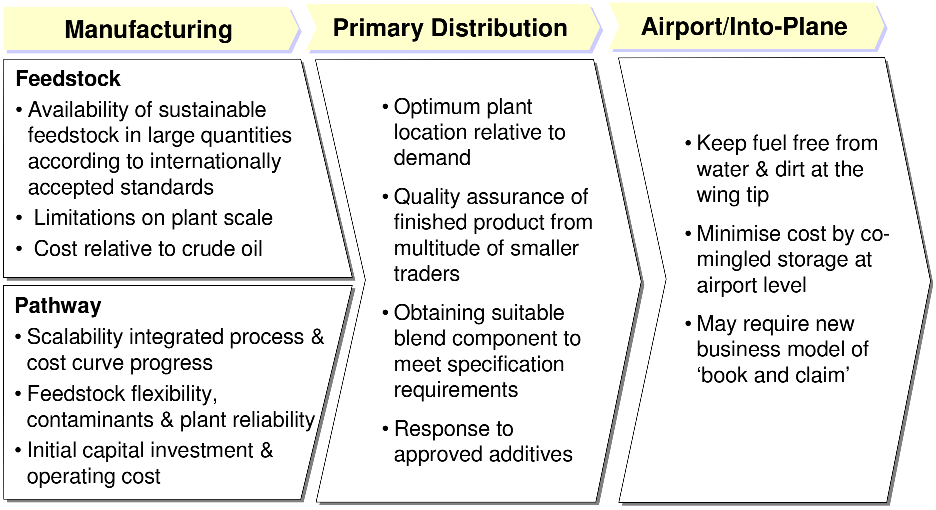


Figure 7. Considerations for introducing an alternative fuel. Credit: Shell.

ENVIRONMENTAL BENEFIT

Many of the alternatives to petroleum-derived jet fuel offer the promise of significant local air quality benefits because of their near zero sulphur content which translates into very low sulphur oxides (SO_x) and particulate matter (PM) emissions. From a climate change perspective, however, the analysis of GHG emissions is more complex. Since the near-term alternative fuels will have properties very similar to today's jet fuel, the combustion of these replacement fuels will result in a release of GHG emissions that are comparable to petroleum-derived jet fuel. The true potential of alternative fuels therefore comes from the natural ability of plants to capture CO_2 that is released into the atmosphere, known as sequestration, and the possible lower GHG emissions in the extraction and production phases associated with bio-feedstock. When this "lifecycle" aspect is considered, some alternative fuels could lead to tremendous environmental benefits.

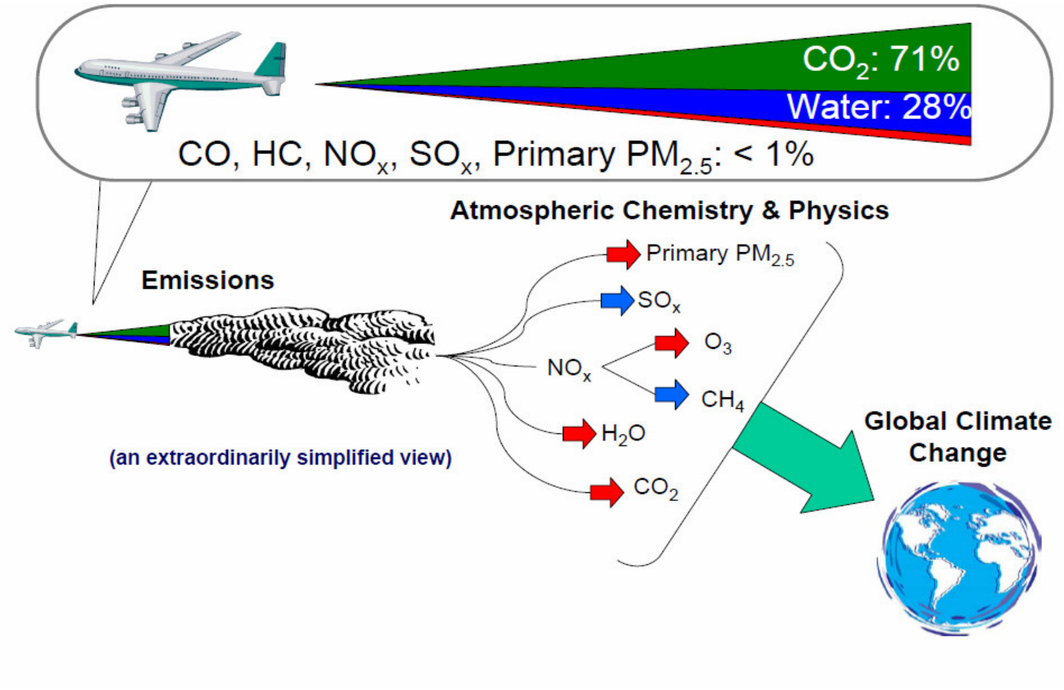


Figure 8. Simple depiction of aircraft "direct emissions" on global climate change. Credit: Massachusetts Institute of Technology.

Figure 8 provides a simple illustration of the effects of combusting a hydrocarbon-based fuel. In this depiction, emissions that have a net warming effect on the environment (viz., primary $PM_{2.5}$, O_3, H_2O, and CO_2) are identified with red arrows and those that have a net cooling effect (viz., SO_x, CH_4) with blue arrows.

As discussed above, the analysis of GHG emissions resulting from the combustion of fuel is only one element of a fuel's lifecycle. **Figure 9** provides an example of parallel lifecycle GHG assessment techniques for traditional petroleum-derived jet fuel and a biomass-based alternative. In her presentation, Ms. Nancy Young, of the Air Transport Association of America (ATA) noted that there was currently no international standard for lifecycle GHG analysis and that ICAO could help the aviation community in its efforts to ensure that one was established that would cover aviation alternative fuels.

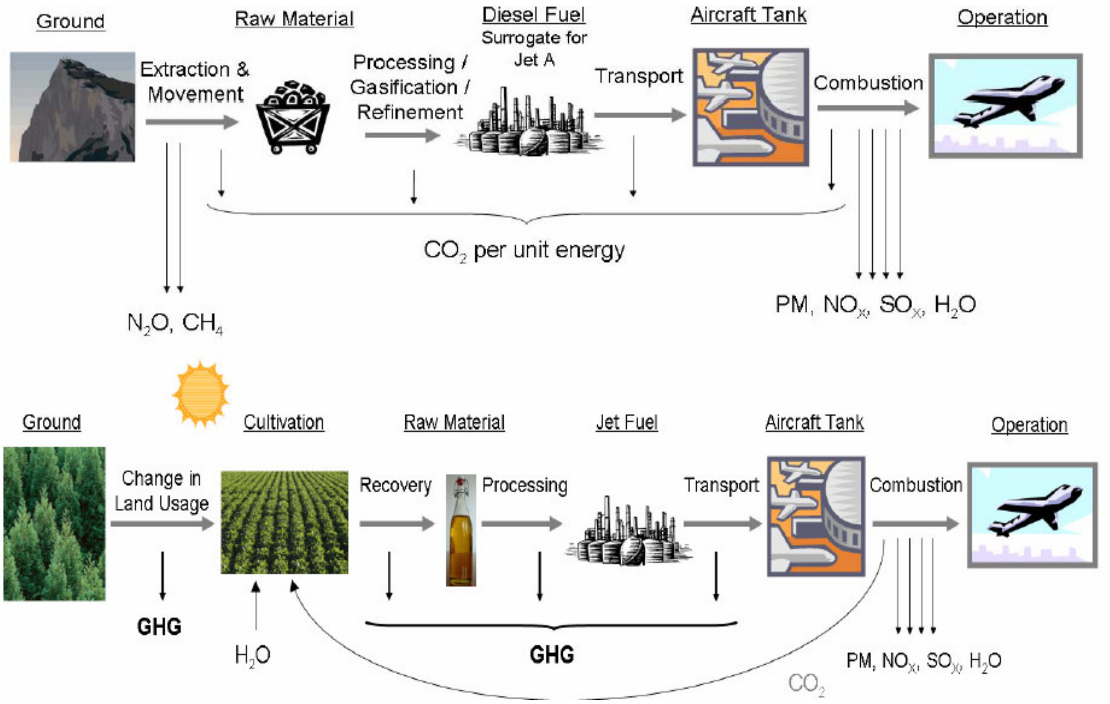


Figure 9. Notional depiction of lifecycle greenhouse gas assessment methodologies for petroleum-derived jet fuel (top) and a biomass-based alternative fuel (bottom). Credit: Massachusetts Institute of Technology.

As **Figure 10** illustrates, research conducted at the Massachusetts Institute of Technology (MIT) shows a significant range in lifecycle GHG emissions relative to conventional jet fuel. In this figure, crude oil to conventional jet fuel is given a value of 1.

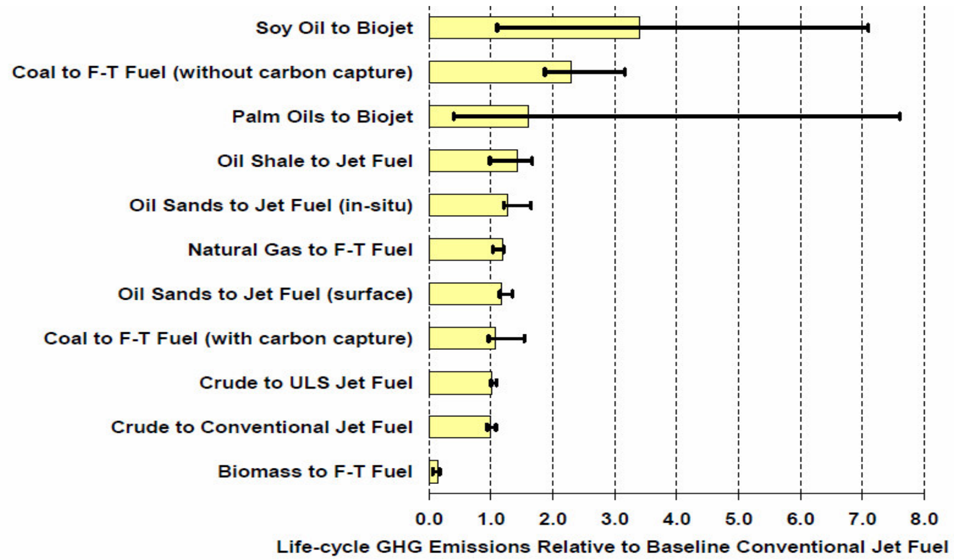


Figure 10. Lifecycle greenhouse gas emissions relative to conventional jet fuel. Credit: Massachusetts Institute of Technology.

According to the studies presented by IEA, it was made clear that for the foreseeable future, oil would remain the leading transport energy source. However, as Mr. Fulton of the IEA indicated, the era of low-cost oil might soon be over. As Mr. John Heimlich, chief economist of the Air Transportation Association showed in **Figure 11**, price volatility could remain or even increase.

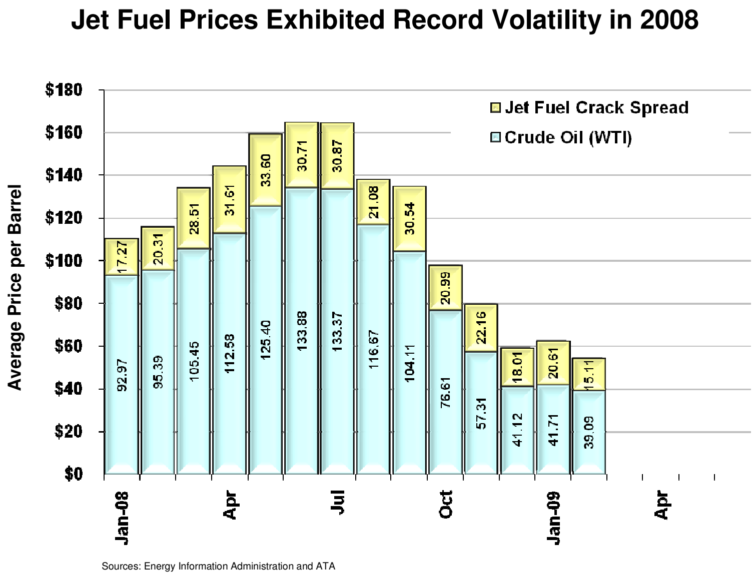


Figure 11. US average price per barrel of jet fuel and crude oil. Credit: Energy Information Administration and Air Transport Association.

As airlines often note, fuel costs represent the largest portion of airline operating expenses, regardless of the price of oil and despite an almost regular level of fuel consumption. Moreover, the price of jet fuel is consistently higher than crude oil and the premium seems to be increasing. These trends are shown in the **Figures 12 and 13**).

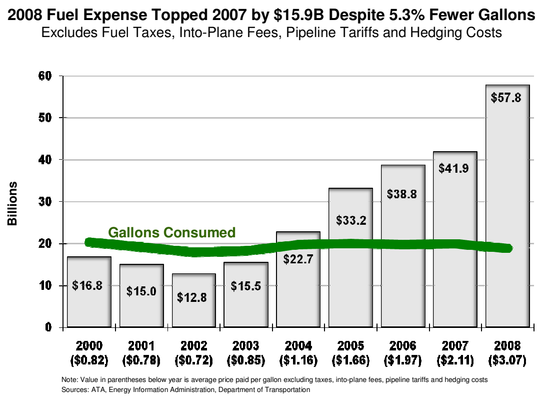


Figure 12. 2008 US Jet fuel prices. Credit: Air Transport Association, Energy Information Administration, US Department of Transportation

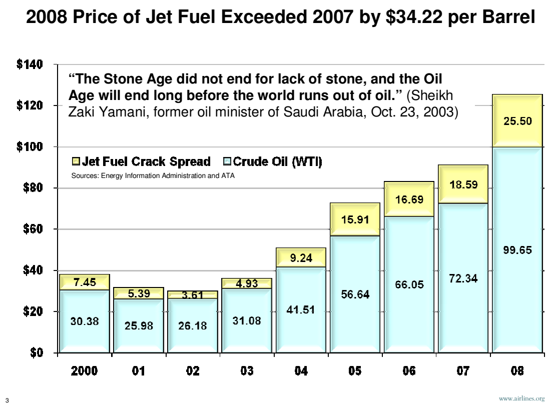


Figure 13. US Jet fuel price trends. Credit: Energy Information Administration and Air Transport Association.

Mr. Dale Smith of Boeing Commercial Airplanes explained that the adoption of alternative fuels by aviation might be simpler than for other sectors due to the relatively small number of fuelling locations and vehicles, as shown in **Figure 14**. During the discussion of the attractiveness of aviation as an alternative fuels customer, Mr. John Heimlich of the Air Transport Association stated that aviation was a unified and committed industry buyer due to the single type of fuel used by its turbine powered equipment. He further explained that aviation would also be a reliable customer since it was clear that aircraft would continue to use liquid fuels in our lifetimes. He foresaw that with proper pricing incentives, individual carriers could agree to long-term contracts directly with producers, with floor prices, if necessary. He finally explained that fuel producers were likely to see a higher return on sales of jet fuel than for diesel.

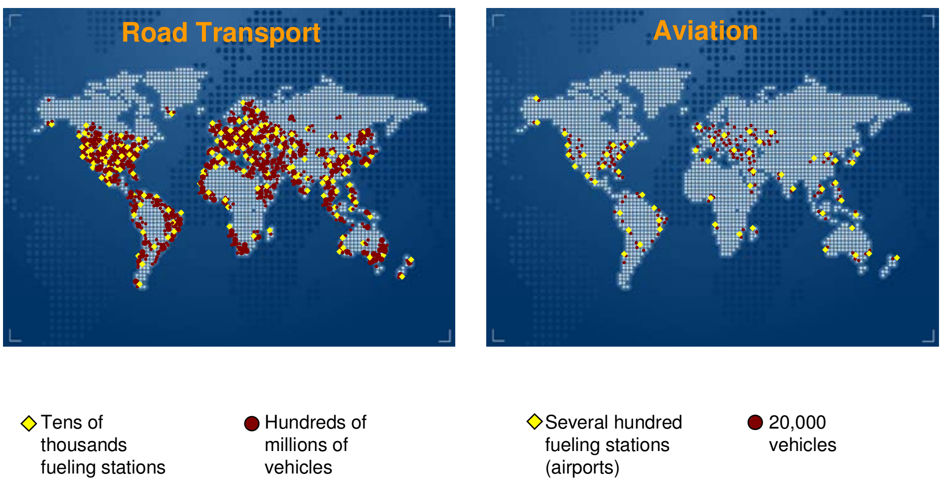


Figure 14. Fuel transition considerations for road transport and aviation. Credit: The Boeing Company.

Dr. Chris Wilson of the University of Sheffield explained that despite noteworthy opportunities generated by alternative fuels, there were significant risks both for producers and users. Above all was the large capital cost of any new project. Investment decisions on large capital projects were said to be risky and especially difficult to make under uncertain economic conditions and with volatile energy markets. In addition, for biofuels, there was uncertainty regarding the feedstock availability and cost (by some estimates 85 percent of a biofuel plant operating cost was feedstock). Dr. Wilson also explained that it was necessary to consider that producers of alternative fuels might find other markets for their fuels to be more lucrative than the relatively small jet fuel industry, and noted that presently, the net costs of alternative fuels, especially biofuels, remained higher than those of conventional fuels.

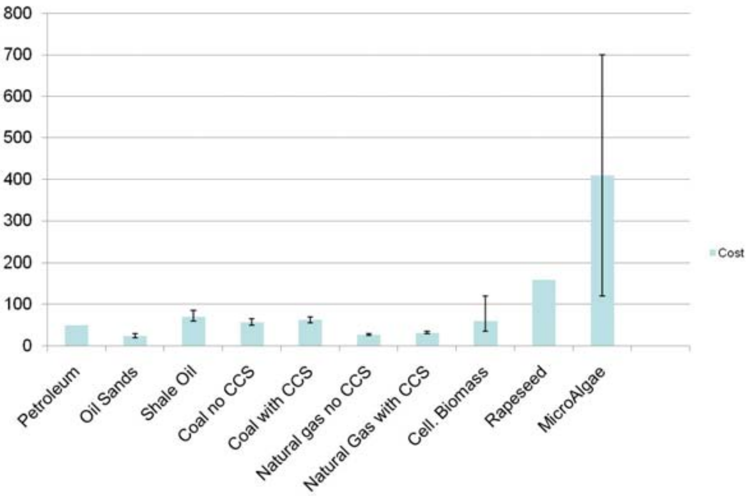


Figure 15. Relative costs of producing jet fuels from different feedstock. Credit: Omega.

It was explained further that due to the high capital and production costs of any alternative fuels, it was important to perform an economic cost versus environmental benefit analysis. In order to encourage the use of environmentally friendly alternative fuels in aviation, it was important to recognize the potential need for incentive mechanisms. These could include State or regional level capital investment incentives or favourable tax regimes. At present, it was added, there was no credit given for alternative fuels in market-based measures. A recognition and appropriate credit for low carbon fuels under emission trading schemes (ETS) and similar schemes would be extremely helpful in promoting their use. Moreover, the uncertainty of global GHG framework made a cost-benefit analysis difficult to perform while clear policy signals would reduce the uncertainty in such analyses.

INTERDEPENDENCIES WITH OTHER FACTORS

A lifecycle analysis, as described in the environmental benefits section, would account for CO_2 emissions in the total life-cycle of any aviation fuels. Mr. Bill Wason of Bio-Pure Fuels explained that there were other important social and environmental considerations that must be well understood or the airline industry could go down the wrong road in looking at sustainability. First and foremost was the food vs. fuel issue. He informed that sustainability parameter was being developed by the Roundtable for Sustainable Biofuels group, suggesting that fuel production must not compete with food production. While there had been some short term impacts on feed costs with some biofuels (corn price and ethanol in USA), the long term opportunity was that of co-production of food and fuel crops on the same land as opposed to the underinvestment in food production. For instance, planting of certain oil seed species (Moringa, Macauba) allowed for co-production of oil seeds and food or grazing animals on the same land. This would allow for increased food production to deal with population pressures and at the same time oil for jet fuel production.

Any selection of feedstock would need to carefully consider existing land use, and use of biomass during any conversion as well as impacts on water use. In addition, feedstock production for any biofuels must not cause deforestation or biodiversity loss. For such reasons, all sustainability parameters must be clearly articulated as "criteria" in a global roadmap.

One opportunity the airlines were said to have due to their potential role as a "carbon buyer" was to proactively participate in efforts to keep high conservation value land, particularly high carbon value land like forests, which could be preserved using economic instruments such as carbon offsets. It was pointed out that airline industries were faced with participation in the EU Emission Trading Scheme in 2012. An alternative was to propose a global carbon trading program for airlines that would allow for the use of "avoided deforestation" and "tree planting" as viable carbon offset options and pursue these projects to "hedge" against much more expensive carbon liabilities should the airlines be required to participate in a more rigid ETS program. This would hedge against high petroleum costs, while ensuring that there were no indirect land use change impacts from oil seed tree production, the primary variable impacting the carbon benefits of oil seed tree crops in tropical countries.

On the other hand, a presenter, Mr. Ancelmo de Góis of Brazil noted that there could be social advantages in purchasing these feedstocks directly from low-income farmers leading to employment in an integrated bioenergy system.

One question that was raised, but not answered, during the workshop was that of quantifying the impact of reduced emissions of PM and other elements at altitude versus their impact at ground level. It was thought that change to alternative fuels may offer a greater environmental advantage for aircraft flying at higher altitude relative to road or marine transport. This is an area for further exploration.

CONCLUSION

Ms. Folasade Odutola, Director of the Air Transport Bureau, presented the main conclusions of the workshop as follows:

Alternative fuels are not the sole means to reduce aviation's GHG emissions, but they are an attractive part of a comprehensive, long-term energy strategy. The decision to develop and use alternative fuels must be an informed and responsible one, taking into account total life-cycle costs and carbon footprints.

As in all successful international undertakings, global cooperation will be essential to ensure the consistent and standardized use of alternative fuels. At this point in time, the international aviation community does not have an integrated approach to alternative fuels. Regional and national consortia have done an excellent job of bringing together the expertise to consider technical issues. However, international facilitation through ICAO can help address it in a more holistic and less fragmented way. As in all other areas of international aviation, ICAO is as committed as ever, to exercising its leadership for achieving effective coordination among all parties involved, be they States, industry or specialized agencies.

The workshop demonstrated that progress is being made and there are high expectations for the use of more environmentally-friendly drop-in alternative fuels for aviation in the short-term. Research is underway with potential for a globally-available alternative fuel in the mid- to long-term, and concerted international action would be necessary to translate this possibility into a reality.

A need to standardize quantification of life-cycle carbon footprints of all fuels was identified. This will be an essential input not only for comparing alternative fuels in terms of their environmental benefit, but also an extremely useful tool in any scheme, market-based or otherwise, which incentivises the use of environmentally friendly alternative fuels. ICAO provides an ideal forum for such discussions.

The presentations from policy makers and regulatory authorities also highlighted the need for a common, standard way of measuring progress in alternative fuels' development. The interesting concept of Fuel Readiness Levels was introduced. Similar to the need for standardized life-cycle analysis, a global framework for measuring technological progress would be desirable. Furthermore, use of standardized vocabulary and terms in alternative fuels discussions would enhance communications considerably.

ICAO realizes that aviation stakeholders represent the leading edge of technology in our society and therefore must lead the efforts to implement solutions that reduce aviation's environmental footprint while allowing economic growth. Research and development in aviation technologies, such as the use of alternative fuels, offers great promise. Aviation, because of its pioneering of technological innovations, can and should be the "first mover" at a global scale for alternative fuels. Once developed for aviation, these technologies will also trickle down to other sectors for an overall better environmental performance.

At this stage it is envisaged that ICAO can assist with:

- Providing a forum for further education on the work being done in the major international specification groups on new alternative fuel specifications

- Facilitating acceptance of standard methodologies for performing life-cycle (well-to-wake) assessments for alternative aviation fuels

- A globally harmonized way of assessing the technology readiness level of aviation fuels

- A standardized vocabulary and definition of terms used in alternative fuels

- Guidance to facilitate airport/airline/distributor/fuel supplier costs and benefits

- Helping the stakeholders align, on an international level, roadmaps and programs to ensure biofuel supply development is coordinated between aviation, agriculture and renewable fuel interests

- Promoting national and government-backed infrastructure investments in synthetic and biofuel pilot plants and possibly full-scale production facilities

The information presented during this workshop provides ICAO and all aviation stakeholders a common basis for the work described above. Global harmonization for alternative fuels, as part of a comprehensive energy strategy will enable the continued growth of aviation, with a diversified fuel supply base in an environmentally responsible manner.

All of the presentations made at the ICAO Workshop on Aviation and Alternative Fuels are available on the ICAO website at: www.icao.int/WAAF2009/Programme.htm

Opening Remarks
ICAO Secretary General, Dr. Taïeb Chérif

1. Keynote speaker:
Mr. Lewis Fulton, International Energy Agency (IEA)

Session 1. Setting the scene

2. ICAO's role and Activities in Aviation Alternative Fuels
Jane Hupe, Chief, Environment Section, ICAO

3. Alternative Fuels: Why do we need them?
John P. Heimlich, VP and Chief Economist, Air Transport Association

4. Why We Need Alternative Fuels
Paul Steele, Director, Aviation Environment, IATA Executive Director, ATAG

5. The Role of Aviation Alternative Fuels in Climate Change Mitigation
Daniel Rutherford, Ph.D., The International Council on Clean Transportation (ICCT)

6. Alternative Fuels: Assessing the Benefits … Addressing the Challenges?
Richard L. Altman, Executive Director, Commercial Aviation Alternative Fuels Initiative (CAAFI)

Session 2. Overview of potential options for alternative fuels

7. Aviation Alternative Fuels … Characterizing the Options
Richard L. Altman

8. SASOL Synthetic Fuels: Coal to Liquids
Piet Roets, Manager Fuels, US CTL, SASOL

9. Gas-to-Liquids: Jet Fuel development
Mohammad Turki Al-Sobai, Qatar Petroleum

10. Alternative Fuels in Qatar Airways: A view from the airlines' perspective
Captain Chris Schroeder, MBA, MSc, Head of Fuel Optimization, Environment & Corporate Social Responsibility, Qatar Airways

11. Gas to Liquid
Philippe Fonta, Head of Sustainable Development, Airbus

12. Alternative Fuels for Aviation: Industry Options and Challenges
Paul Bogers, Shell Aviation

13. Overview of Potential Options for Alternative Fuels
Leah Raney, Continental Airlines

14. Pathways to Sustainable Travel w/ Biofuels & Carbon Trading
Bill Wason, BioPure Fuels

15. Creating Alternative Fuel Options for the Aviation Industry: Role of Biofuels
Jennifer Holmgren, UOP

16. JAL Biofuel, Flight Demonstration
Yasunori Abe, Environmental Affairs, Japan Airlines

17. Algae: The Source of Reliable, Scalable, & Sustainable Aviation Fuel
Brian L. Goodall, Sapphire Energy

18. Subsonic Fixed Wing Project: N+3 (2030-2035) Generation Aircraft Concepts - Setting the Course for the Future
Fay Collier, NASA

19. Biofuels
Mauro Iurk Rocha, Petrobras, R&D Center – CENPES

Session 3. Challenges to development and deployment of alternative fuels

20. Challenges to Development and Deployment
Dr. Ebad Jahangir, Environment Section, ICAO

21. Challenges to alternative aviation fuels - Policy makers' perspectives
Doris Schröcker, European Commission

22. Alternative Fuels, R&D – A U.S. Perspective
Dr. Lourdes Maurice, United States FAA Office of Environment & Energy

23. Alternative Fuels in Aviation – Embraer View
Alexandre Tonelli Filogonio, EMBRAER

24. Alternative Fuel Challenges - An aircraft manufacturer's view
Philippe Fonta, Airbus

25. Certification of Alternative Fuel
Mark Rumizen, CAAFI Certification Qualification, FAA Aviation Fuels Specialist

26. Insights into Jet Fuel Specifications
Ravin Appadoo, Commport Aerospace Services Ltd

27. Overview of the relationship between fuel properties and engine performance
Nader Rizk, Rolls-Royce

28. Environmental Drivers and Challenges, The Big Picture
Nancy N. Young, Air Transport Association of America, Inc.

29. Environmental Assessments Status
Dr. Lourdes Maurice, CAAFI Environmental Team Lead and Federal Aviation Administration Chief Scientific and Technical Advisor for Environment

30. Environmental assessments/initiatives (life cycle assessment, air quality measurement; international initiatives)
Chris Wilson, University of Sheffield

31. The Challenges of Implementation & Deployment of Alternative Fuels
Paul Bogers, Shell Aviation

32. Production and distribution of Sasol semi synthetic Jet A-1
Piet Roets, SASOL

33. Jet Fuel Purchases: Airline Perspective
Hortencia Barton, American Airlines

34. Airports and alternative fuels
Xavier Oh, Airports Council International

Session 4. Initiatives to promote cooperation

35. Examples: Cooperation from the policy perspective
Doris Schröcker, European Commission

36. Examples: Brazil
Ancelmo de Góis, Brazil

37. Examples: The CAAFI Coalition Why? What? How? …. A template for International Cooperation
Richard Altman, CAAFI

38. Examples: Jet fuels and the road to future Jet fuels
Michel Baljet, IATA

39. Examples: Demonstrating Commitment with Action
Dale Smith, Boeing

40. Closing remarks:
Ms. Folasade Odutola, Director, Air Transport Bureau, ICAO

ACKNOWLEDGMENTS

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The panel moderators and panellists themselves played a substantive role in the workshop, and their exceptional contributions are noted throughout this report.

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This summary was prepared by Dr. Ebad Jahangir and Mr. Theodore Thrasher, Officers from the ICAO Environment Section.