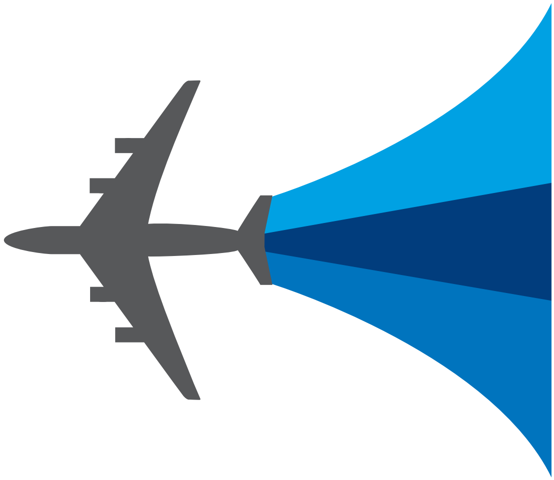

PART I

INTRODUCTION AND CONTEXT

1 INTRODUCTION

Augusto Barbosa Cortez [et al.]. "Introduction", p.19-28. In: Luís Augusto Barbosa Cortez (Editor). **Roadmap for sustainable aviation biofuels for Brazil — A Flightpath to Aviation Biofuels in Brazil**, São Paulo: Editora Edgard Blücher, 2014.
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1 INTRODUCTION

Created and developed during the last century, the aviation industry, encompassing the airplane and aeronautic equipment industry, airlines, national defense forces, and general and business aviation companies, airports and all ancillary organizations, is nowadays an essential component of modern economy and life and has been growing at important rates, mainly in developing countries. In this expansion process, to ensure a sustainable, competitive and environmentally sound energy supply is a challenging question.

The Sustainable Aviation Biofuels for Brazil Project is an initiative of BOEING, EMBRAER and FAPESP chartered to set a R&D agenda for effective development of production routes of these biofuels, considering the use of proper feedstock, processed by innovative technologies to reach the requirements of a drop-in fuel, under strict sustainability constraints. The project has been developed during 2012 using the methodology of organizing a series of workshops to discuss every relevant issue concerning aviation biofuels and progressively designing a "roadmap" to be adopted in order to overcome the identified hurdles and effectively introduce biofuels in the regular air transportation system.

To introduce the context of the Sustainable Aviation Biofuels for Brazil Project, this session presents an overview on: aviation industry and energy, modern biofuels situation, and aviation biofuels evolution in recent years, highlighting the role of government actions in the regulatory and incentives spheres.

After these introductory subjects, the chapter goes more deeply into what was presented and discussed in the 1st Workshop of the Project, confirmed when the vision and scope of the project was confirmed by the Stakeholders, and follows on to discuss the necessary aspects to establish a Technology Road Map (TRM).

1.1 Aviation Industry and energy

The civil aviation is absolutely essential to the global economy. According to the International Air Transport Association, the air transportation industry contributes about US$ 3.8 trillion per year to the global economy, supporting the employment of 32 million people, to transport 42 million tonnes of goods and connect 2.8 billion people. One daily international long haul flight generates, in annual terms, 60 thousand passengers, 880 jobs, US$ 26 million in GDP (Gross Domestic Product), US$ 10 million in salaries and US$ 4 million in taxes (IATA, 2012).

In Brazil, air transportation is evolving rapidly, higher than the global average. Brazil is currently forecasted to become one of the largest domestic air traffic market in the world by 2014. In 2010, the Brazilian aviation sector carried over 71 million passengers and 870 thousand tonnes of air freight to, from and within Brazil. More than 62 thousand scheduled international flights depart Brazil annually, destined to 58 airports in 35 countries. Domestically, more than one million scheduled flights annually provide connections between 108 airports. In economic terms, in 2009, this activity contributed with R$ 32 billion to Brazilian GDP and employed about 684 thousand people. In addition, it is estimated that there are a further 254 thousand people employed through activities promoted by aviation, such as tourism (OXFORD ECONOMICS, 2011).

The aviation sector contributed over R$ 4.0 billion in taxes through corporation tax and income and social security contributions (both employee and employer contributions). Air passengers paid a further R$ 1.3 billion in passenger embarkation taxes, bringing the total tax contribution to R $5.3 billion. Moreover, it is estimated that a further R$ 7.2 billion of government revenue is raised via taxation through the indirect (R$ 4.4 billion) and induced (R$ 2.8 billion) channels. Not included in the figures above are domestic aviation fuel tax payments, estimated to be in the range of R$ 0.8-1.2 billion (OXFORD ECONOMICS, 2011).

The energy demand of the aviation industry is almost totally focused on petroleum based jet fuel, a form of kerosene, which has good properties to be used in jet gas turbines efficiently and safely. The global demand of jet fuel is around 250 million cubic meters per year, close to 6% of refinery output (IEA, 2011). About 2/3 of that demand occurs in OECD countries. In Brazil, the demand for jet fuel in 2011 was approximately 7 million m^3 (about 2.8% of global demand) of which the Brazilian refineries produced 75% and the rest was imported from various countries (ANP, 2012).

Figure 1 presents the projected growth of jet fuel consumption in Brazil, together with the historical evolution of production and consumption in the last 12 years. According to Sindicom, jet fuel consumption is projected to reach 12 million m^3 by the year 2020 while the number projected by EPE (EPE, 2011) is 11 million m^3 for the same year, with an annual growth around 5%. The steep increase in production, projected around 2015 due to new refineries going into operation, will have some postponement following the investment plans of Petrobras recently made public (PETROBRAS, 2012). The equilibrium between supply and demand will only occur several years later.

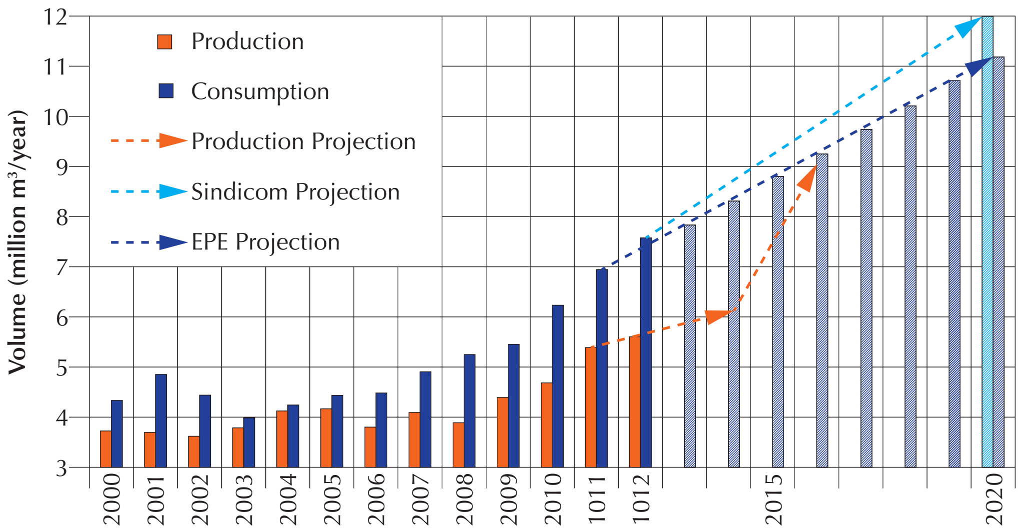

Figure 1 Jet fuel consumption and production in Brazil. Source: ANP, 2012.

Fuel represents the most relevant operational cost for an airline. As a world average fuel currently represents 34% of the operational costs (compared with 10-15% in the past decade), but in Brazil it is higher, representing around 40% of the operational cost for the airlines. Besides this high share, the volatility associated to oil price variation is another concern, introducing significant difficulties for planning and management in these companies. **Figure 2** presents the evolution of oil (referenced as Brent) and international jet fuel prices in the last years.

The pricing of jet fuel is usually done according to three models: market based formula, import parity and posted price. In market based pricing, an average spread over crude oil is US$ 9.6 per barrel. The jet fuel price at the producer gate in Brazil, about 1.0 to 1.2 US$/liter in 2011[1], is defined by Petrobras and taxed multiple times. The domestic jet fuel price is 12% higher than the regional South American and 17% higher than the global average (EBNER, 2012a).

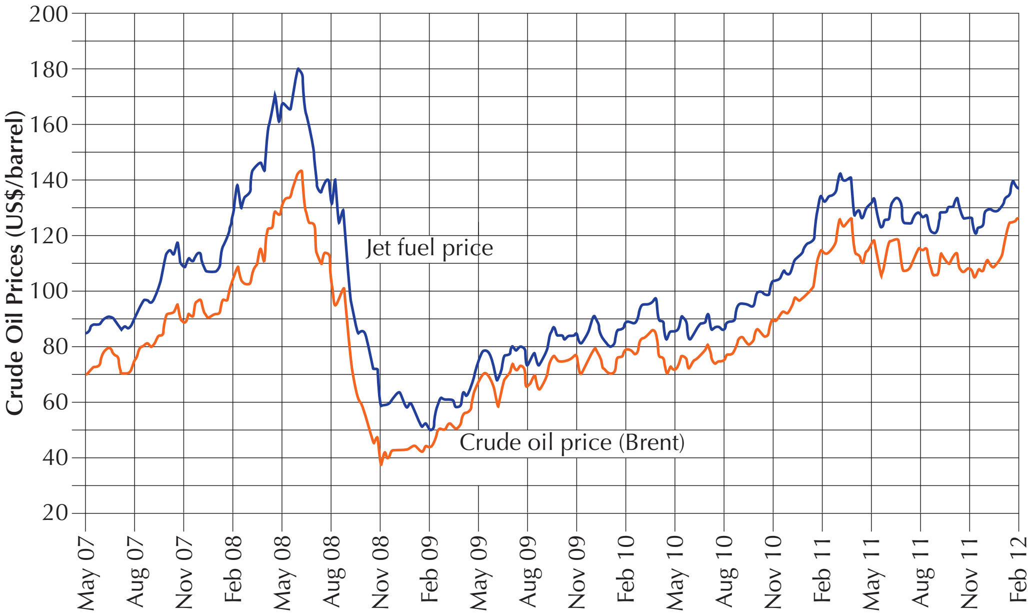

Figure 2 Crude oil and jet fuel prices in US$/barrel. Source: IATA, 2012.

1.2 Biofuels and GHG emissions

The concern about global climate change, as well as high prices and uncertainty in oil supplies have led to a growing demand for renewable energy technologies and more efficient process of energy conversion. In this context, the production and use of ethanol and biodiesel have developed dramatically in recent decades, essentially seeking to meet the demand for light and heavy vehicles used in road and urban transport. The evolution of global biofuel production is shown in **Figure 3**. Biofuels currently represent about 3% of global energy consumption to move people and goods.

The photosynthetic route of solar energy harnessing to produce liquid fuels has been deeply evaluated and, in despite of the misunderstanding remaining in some circles, there is an increasing knowledge on sound bases indicating that in several production routes (feedstock

1 A barrel of oil has approximately 159 liters.

production and processing) the sustainability indicators, assessing environmental, social and economic aspects, can be and in some already are very positive. As a consequence of this perception of biofuels potential and advantages, projections from institutions such as the International Energy Agency and the World Energy Council point to vectors a rising share in the future demand for this renewable energy.

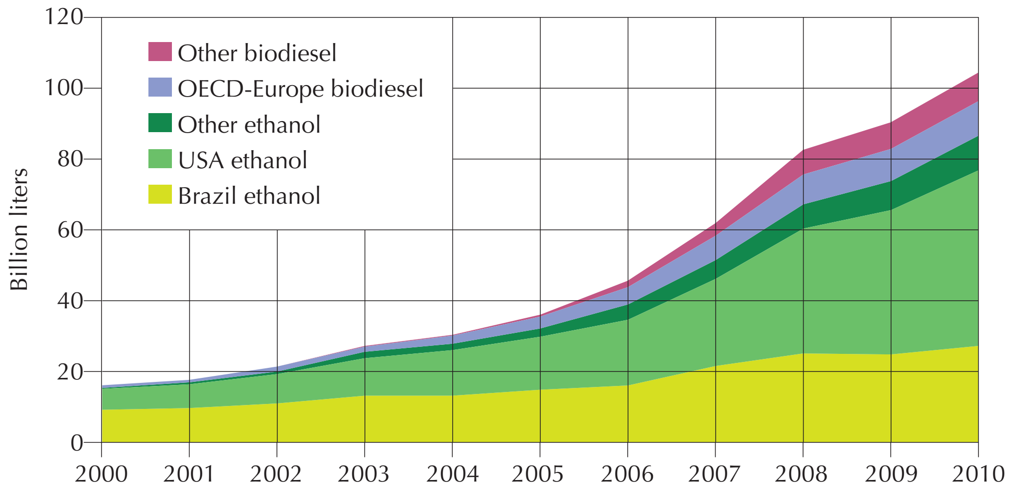

Figure 3 Biofuels global production. Source: IEA, 2010.

Figure 4 presents a synthesis from the IEA study (Blue Map scenario), estimating that in 2050 biofuel can represent about 27% of global energy demand in transport, about 116 EJ. Biofuels are expected to contribute to all modes, but road transport (63%) and aviation (26%) should take the most relevant share.

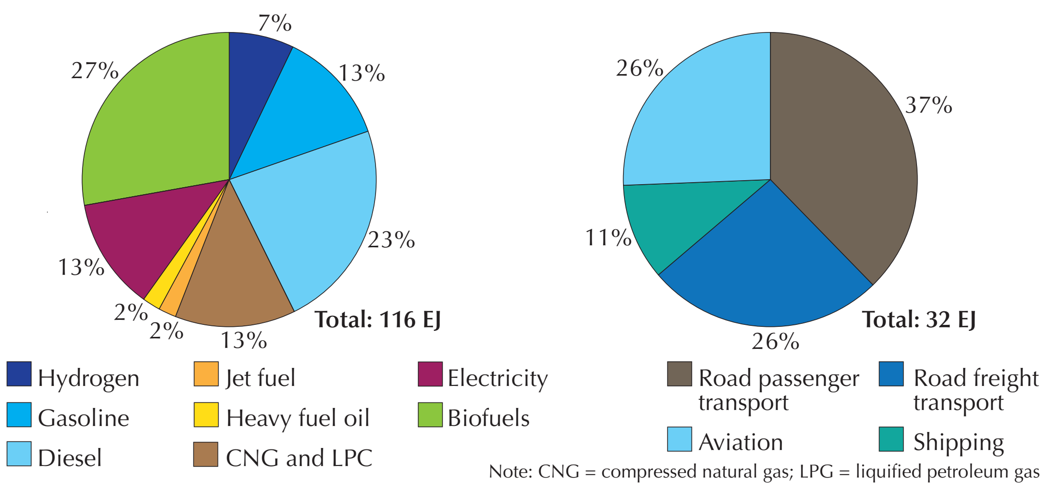

Figure 4 Global energy use in the transport sector (left) and use of biofuels in different transport modes (right) in 2050 (BLUE Map Scenario). Source: IEA, 2010.

The Brazilian experience on liquid biofuels

In Brazil, about half of the total primary energy comes from renewable sources, mainly hydro, sugarcane and wood. The importance of the sugarcane bioenergy is high; in 2011 it accounted for 15.7% of the national energy supply (42.8 Mtoe), slightly above the contribution of hydroelectric power (EPE, 2012). In the road transport sector, biofuels were responsible for about 19% of total energy consumption in 2011.

The extensive Brazilian experience with automotive biofuel started in 1931 with the mandatory blending (5%) of ethanol from all gasoline commercialized in gas stations. In 1975, the Brazilian Ethanol Program induced a large expansion of production, by the progressive improvement of agro-industrial productivity, with the use of 25% ethanol gasoline blends and introduction of pure ethanol cars. After 1985, with the decline of oil prices, the stimulus to ethanol was reduced. Production stagnated until the introduction of flex-fuel cars in 2003. These cars represent today about 93% of sales of new cars. In 2013, straight ethanol can be used by 20 million Brazilian vehicles (mostly cars with flex-fuel engines), around 50% of the national light vehicle fleet (ANFAVEA, 2013). In the 2010/2011 harvest season, 9.2 million hectares of sugarcane fields (approx. 1% of Brazilian national area) produced 620 million tonnes of feedstock for sugar, ethanol and electricity. About 50% of the available sugar was used to produce 22.6 million cubic meters of ethanol in 2011 (UNICA, 2014). During the last decades, productivity grew at a cumulative average annual growth rate of 3.1%, in ethanol production per hectare, a noteworthy gain in productivity obtained through the steady incorporation of new technologies.

The National Program of Biodiesel Production and Use was launched in 2005, aiming to encourage small producers and farmers from least developed regions to become involved with biodiesel production and setting a progressive use of mandatory biodiesel blends in all diesel oil sold in gas stations. This blending obligation started in January 2008 with 2% biodiesel (B2) until reaching the B5 from January 2010 on. In this condition, the production of biodiesel has increased exponentially and reached 2.67 Mm^3 in 2011, based mainly on soybean (80%) and tallow (14%) (EPE, 2012).

1.3 GHG Emissions and Biofuels in Aviation

Beyond the concerns on energy costs, the awareness of the environmental impact of fossil fuel utilization, mainly related to GHG emissions, has increased significantly in the context of the aviation industry. Although the air transport currently accounts for about 2% of human-made carbon dioxide emissions, this participation is growing rapidly. If fuel consumption and CO_2 emissions were to continue growing at present rates, CO_2 emissions by worldwide aviation in 2050 would be nearly six times the current figure.

Historically, significant fuel efficiency gains have been achieved by operational improvements (such as higher load factors, utilization of larger aircraft) and by technical progress (such as more efficient engines, aerodynamics, lighter airframes). Even with this efficiency improvement, aviation CO_2 emissions are predicted to more than triple by 2050 (EC, 2011).

To address the presage of climate change and emissions from the aviation sector, some public policies responses are being developed. In this direction, the most relevant measure is the European Union Emissions Trading Scheme (EU ETS), launched in 2005 to be introduced in progressive tiers and representing relevant additional costs to the sector (OAG, 2012). Enforcement is currently suspended while negotiations for an international aviation emissions framework are underway through the International Civil Aviation Organization. According to this legislation, starting in 2012, aircraft operators (for passengers, cargo and non-commercial flights) will have to surrender an allowance per ton of CO_2 emitted on a flight to/from (and within) the European Union. This will create new costs for the entire sector of about 3.5 billion Euros per year assuming a price level of 30 Euro per allowance, introduced in progressive tiers (OAG, 2012).

Nevertheless, compared with the conventional liquid biofuels, the adoption of biofuels in aviation faces more challenging conditions, especially due to the the consumption and the high quality requirements to be met by a fuel to be used in modern aircraft engines. Thus, to reach effective technical feasibility and proper conditions to develop an international market, the aviation biofuels must have a high energy density and meet the stringent quality specifications; provide good indicators of environmental sustainability and achieve minimum levels of economic competitiveness. As an additional and relevant constraint, taking into account the global specification of jet fuel and its use distributed among many countries, it is imperative to implement aviation biofuels under the concept of "drop-in" fuel[2], as well as enhancing the operational safety as a core concept.

At present there is no sufficient clarity on feedstock and processing technologies with better potential and competitiveness (current and future), subject of analysis and discussion in the Sustainable Aviation Biofuels for Brazil Project workshops, although several pathways have been identified. Nevertheless, there are sufficient elements to indicate that the aviation biofuels, although using the background and experience achieved with the conventional biofuels (ethanol and biodiesel), represent a totally new frontier for bioenergy, imposing a new vision of the development of energy agroindustry.

As a clear sign of the interest and commitment of the aviation industry towards the development of aviation biofuels, there are an increasing number of initiatives promoting them, as presented in **Figure 5**, including demonstration flights, indicating clearly that this energy technology has been associated, from the beginning, as innovative and environmentally responsible action. Among those initiatives, it is worth noting:

1. the Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE) promoted in 2010 a study about the introduction of jet biofuels in aviation in Brazil;
2. the creation of the Brazilian Alliance for Aviation Biofuels (ABRABA, Aliança Brasileira para Biocombustíveis de Aviação) joining Brazilian companies "to discuss the various aspects of developing sustainable aeronautical biofuels driven by the growing demand to meet the requirements for reducing greenhouse gas emissions in aviation as well as to provide support for Brazil's energy security" (ABRABA, 2012);
3. the Civil Aviation Environmental Goals definition by the International Civil Aviation Organization (ICAO), aiming to minimize the adverse effect of civil aviation on the environment and including actions to limit or reduce the impact of aviation GHG

2 "Drop-in biofuels" are biofuels that can be mixed with conventional jet fuel, can use the same supply infrastructure and do not require adaptation of aircraft or engines.

emissions on global climate using sustainable biofuels and efficiency gains as key elements. This agency launched the ICAO Global Framework on Aviation Alternative Fuels (GFAAF) (ICAO, 2013);

4. the creation by the US Federal Aviation Administration (FAA) of the Commercial Aviation Alternative Fuels Initiative (CAAFI), chartered to “enhance energy security and environmental sustainability for aviation through alternative jet fuels” (CAAFI, 2012), in a context where the biofuels are one prominent alternative;
5. the inclusion, in 2011, of aviation biofuels in the framework of the European Industrial Bioenergy Initiative, an important element of the EU’s energy and climate change policy (EC, 2011). Also under EU sponsorship was issued the study Sustainable Way for Alternative Fuels and Energy for Aviation (SWAFEA);
6. in 2011 of the report Flight Path to Sustainable Aviation by the Commonwealth Scientific and Industrial Research Organization (CSIRO), focused a sustainable aviation fuels industry in Australia and New Zealand (CSIRO, 2011);
7. in December 2012, the European Commission postponed the full implementation of the European Trading Scheme in response to ICAO demand to treat the subject in an international forum (EU, 2012).

Many demonstration and commercial flights have been staged, involving more than 20 airlines worldwide, flying with jet fuel made out of a variety of feedstock including used cooking oil and oil crops such as rapeseed, jatropha, camelina, and palm oil (as shown in **Figure 5**, **Table 1** and **Table 2**)

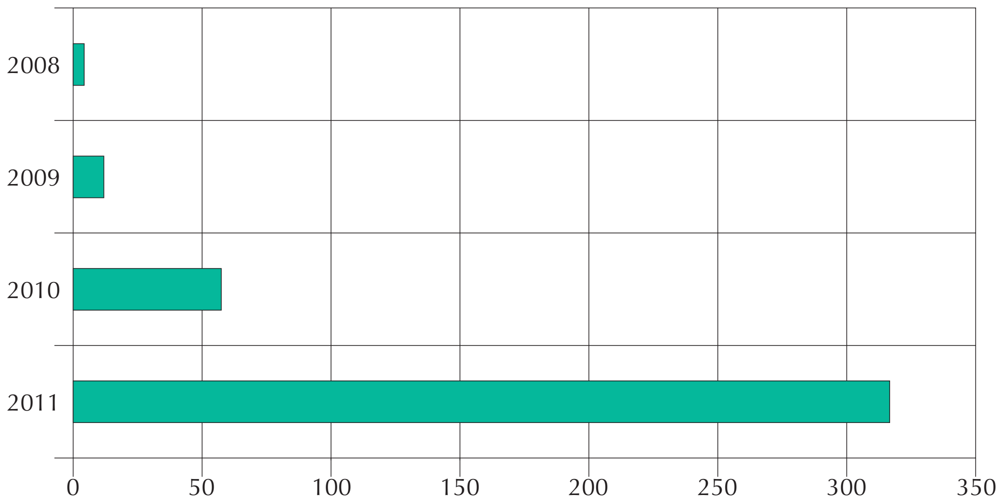

Figure 5 Number of initiatives on aviation biofuels. Source: Hupe, 2012.

During the Conference Rio+20, two Brazilian airlines made demonstration flights employing biofuels. Azul Airlines flew an EMBRAER E-195 using a drop-in renewable jet fuel produced from sugarcane by Amyris. A lifecycle analysis and sustainability study developed by the Institute for International Trade Negotiations (ICONE), indicates that this renewable jet fuel could reduce greenhouse gas emissions up to 82%, when compared to conventional fossil-derived jet fuel. In the same day, Gol Airlines made another demonstration with a BOEING 737-800 using jet fuel blended with biofuel derived from inedible corn oil and used cooking oil supplied by UOP. Before that, in 2010, TAM had already tested a jet fuel containing 50% of fuel made with jatropha seeds produced in Brazil. Recently, in October 23th 2013, Gol Airlines made the first commercial flight in Brazil using jet biofuels. The flight was realized with a Boeing 737-800 departing from São Paulo to Brasília using a bio jet fuel blend (with 25% of bio jet fuel). The biofuel used was a HEFA SPK made from a mix non-edible corn oil from corn ethanol production and used cooking oil. The company goal will be to realize 200 flights using jet biofuels blends during de Brazilian World Cup in 2014 (GOL, 2013).

This impressive set of flights assures the technical feasibility of regular use of biofuels in aviation, opening a new and challenging phase: to produce aviation biofuels competitively, respecting the environment and promoting social development.

Table 1 Recent dtbelaemonstration flights using biomass derived jet fuel (ICAO, 2011).

DATE	AIRLINE	AIRCRAFT	ENGINE	PARTNER / FUEL SUPPLIER	SOURCE OF LIQUID JET FUEL BLEND
Feb 2008	Virgin Atlantic	B747-400	GE CF6-80C2	Imperium Renewables, Boeing	20% coconut and babassu
Dec 2008	Air New Zealand	B747-400	Rolls-Royce RB211-524G	UOP, Terasol, Boeing	50% jatropha
Jan 2009	Continental Airlines	B737-800	CFM International CFM56-7B	UOP, Terasol, Sapphire Energy, Boeing	47.5% jatropha, 2.5% algae
Jan 2009	Japan Airlines	B747-300	Pratt & Whitney JT9D-7R4G2	Nikki Universal/ UOP, Sustainable Oils, Boeing	42% camelina, 7.5% jatropha, 0.5% algae
Dec 2009	KLM	B747-400	GE	GE, Honeywell, UOP	50% camelina
Nov 2010	TAM Airlines	A320	CFM International	UOP	50% jatropha
Apr 2011	Interjet	A320	CFM International	CFM, Safran, EADS, Airbus, Honeywell, ASA	27% jatropha

Table 2 Commercial flights using biomass derived jet fuel (ICAO, 2012).

DATE/ROUTE	CARRIER	AIRCRAFT	FEEDSTOCK	NOTES
23 November 2009 Amsterdan - Paris	KLM	B747	Camelina	
29 June 2011 Amsterdam - Paris	KLM	B737	Used Cooking Oil	200 city pair flights from Sept. 2011
15 July 2011 Hamburg - Frankfurt	Lufthansa	A321	Jatropoha, camelina, plants & animal fats	1,200 flights over six-month period
20 July 2011 Amsterdam - Helsinki	Finnair	A319	Jatropha	
21 July 2011 Mexico City - Tuxtila Gutierrez	Interjet	A320	Jatropha	
1 August 2011 Mexico City - Madrid	AeroMexico	B777	Jatropha	First biofuel transatlantic flight
3 October 2011 Madrid - Barcelona	Iberia	A320	Camelina	
6 October 2011 Birmingham - Arrecife	Thomson	B757	Used Cooking Oil	
13 October 2011 Toulouse - Paris	AirFrance	A321	Used Cooking Oil	Flight used 50% biofuel blend
27 September 2011 Mexico City to San Jose, Costa Rica	AeroMexico	Boeing 737-700	15% blend of camelina-derived jet biofuel	Weekly flights
7 November 2011 Houston to Chicago	United	B737-800	40% blend of biofuel made from algae	First USA biofuel commercial flight
9 November 2011 i) Seattle to Washington ii) Seattle to Portland	Alska Airlines	B737-800	20% biofuel blend made from cooking oil	First of 75 flights
22 December 2011 Bangkok to Chiang Mai	Thai	Boeing 777-200	Used Cooking Oil	
12 January 2012 Frankfurt to Washington DC	Lufthansa	Boeing 747	Biosynthetic fuel	
7 March 2012 Santiago to Conception	Lan	Airbus A320	Used vegetable oil	
13 April 2012 Sydney to Adelaide	Qantas	Airbus A330	Used Cooking Oil	Australia's first commercial biofuel flight
17 April 2012 Toronto to Ottawa	Porter	Bombardier Q400	Camelina sativa and Brassica carinata	

Institutional issues

Similarly to other innovative technologies, the development of aviation biofuels depends strongly on support mechanisms and proper public policies. As an immediate example, the adoption of ethanol and biodiesel in many countries required specific and active policies in order to reduce uncertainties and risk perception among producers and promote investments, as well as to protect consumers and the environment.

The basic reasons behind these measures are the differential advantages and externalities of using renewable energy in comparison with conventional fossil fuels. In fact, when produced and used sustainably, a biofuel is able to foster environmental benefits, jobs generation, economic activity and energy security, as main positive impacts. It is important to stress that these potential advantages of biofuels are intrinsically dependent on the production route adopted, including the feedstock productive system and the agro-industrial conversion process, which should be properly assessed by sustainability indicators.

Two basic governmental actions to support the development of sustainable biofuels are the promotion of R&D activities and the definition of a fuel specification. Regarding the first one, in the agriculture, forestry, processing and refining contexts, there are many gaps to fill, open questions to explore and processes to improve. Some feedstock proposed for aviation biofuel production, such as jatropha and algae are relatively unstudied, requiring more assessment. Venture capital can play a complementary role, and one which may be especially relevant in the case of crops such as jatropha and camelina that have a relatively small public research infrastructure but have substantial private funds for R&D. However, clearly it is a government responsibility in concert with industry to organize the scientific and technological development, stimulating basic studies, promoting demonstration projects and, as an essential matter, preparing and motivating researchers. Only with proper resources applied in a broad research agenda is it possible to screen the large number of options for aviation biofuels production systems and choose wisely the most promising ones. That R&D effort should be long-term; in order to optimize the biofuel chain.

The aviation biofuel specification must meet simultaneously to the environmental, engine and producers requirements, which are in conflict in many cases, and impose a judicious analysis before the final decision. In the case of aviation, the globalization of demand and stringent conditions of use and safety standards imposes the “drop-in” concept. A widely accepted procedure for biofuel approval process is already available (ASTM D4054, *Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives*). The ASTM standards for aviation fuels are currently under review by ANP, the regulatory agency with legal mandate for setting fuel specifications in Brazil.

After this introduction dealing with the context of the “Sustainable Aviation Biofuels Brazil Project”, the next sections present the vision and scope of the project, as consensously agreed by the Stakeholders during the 1st workshop.