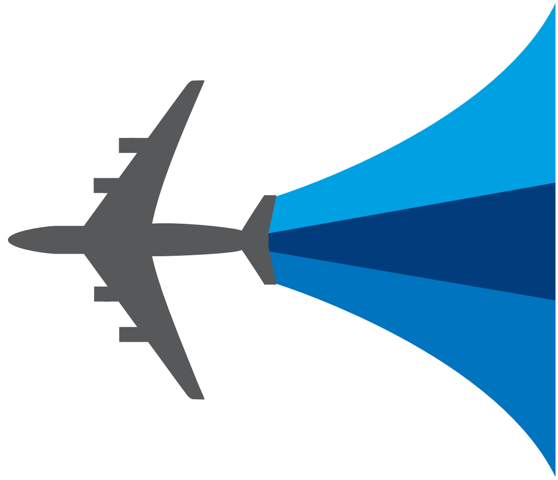

PART I

INTRODUCTION AND CONTEXT

3 CURRENT INDUSTRY: PRODUCTS, PROCESSES, SUPPLIERS AND CUSTOMERS

Augusto Barbosa Cortez [et al.]. "Current industry: products, processes, suppliers and customers", p.37-49. 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.
http://dx.doi.org/10.5151/BlucherOA-Roadmap-003

3 CURRENT INDUSTRY: PRODUCTS, PROCESSES, SUPPLIERS AND CUSTOMERS

3.1 Aviation Fuel Industry in Brazil

In order to set the ground for the future energy supply of the aviation industry, this section defines where the industry is, by means of a summary of the current industry in terms of products, consumers, producers, suppliers, materials and sources of energy used.

It is recognized that airplane transportation is growing fast in Brazil in the last decade. The progress was presented in the 1st Sustainable Aviation Biofuels for Brazil Project Workshop (**Table 4**) by ANP (PINTO JR., 2012).

Table 4 Brazilian Transportation Biofuels (ANP apud PINTO JR., 2012).

FUEL (million m^3)	2011	2010	2009	2008	2007	2006	Variation %
Biodiesel	**2.67**	**2.39**	**1.61**	**1.17**	**0.40**	**0.07**	**3770.61%**
Anhydrous Ethanol	10.72	15.07	16.47	13.29	9.37	6.19	73.25%
Hydrated Ethanol	8.38	7.46	6.35	5.03	4.87	4.80	74.58%
Total Ethanol	**19.10**	**22.54**	**22.82**	**18.33**	**14.23**	**10.99**	**73.83%**
Jet Fuel	**6.96**	**6.25**	**5.43**	**5.23**	**4.89**	**4.47**	**55.74%**
Aviation Gasoline	0.07	0.07	0.06	0.06	0.05	0.05	34.67%
Gasoline C	35.45	29.84	25.41	25.17	24.33	24.01	47.67%
Gasoline A	27.07	22.33	19.06	20.14	19.46	19.21	40.94%
Diesel Fuel	51.78	49.24	44.30	44.76	41.56	39.01	32.75%
LPG	12.87	12.56	12.11	12.26	12.03	11.78	9.20%
Fuel Oil	3.67	4.90	5.00	5.17	5.53	5.13	-28.39%

Also, the growing jet fuel consumption in Brazil is following the GDP growth as presented by Nigro (2012), fact that can be used to estimate future jet fuel demand as given in **Figure 12**. Another important aspect of Brazilian market is shown in the same figure, where the jet fuel consumption grew faster in the State of São Paulo, particularly after the nineties, because most of international flights (both passengers and cargo) have used the airports of São Paulo.

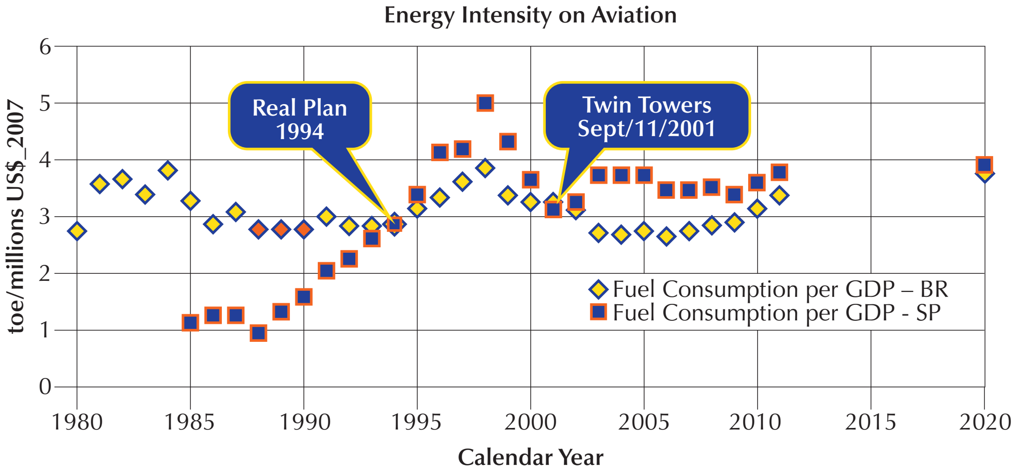

Figure 12 Energy needs for transportation segments. Source: MME/BEN, BEESP, ANP apud Nigro, 2012.

As far as Brazilian commitment with international targets regarding CO_2 reduction in the aviation industry, in March, 2011 President Dilma and President Obama made a joint declaration regarding the implementation of efforts to a partnership between the U.S. and Brazil on biofuels for aviation.

Regarding the Brazilian market, ANP (PINTO JR., 2012) presented the jet fuel consumption growth in the last decade (**Figure 13**). ANP is the regulatory agency responsible for controlling different aspects of the Brazilian fuel market, including quality control. During the presentation in the 1st workshop it was also clear that ANP will cooperate with the biofuels in aviation initiative, with the following statements made during the presentation:

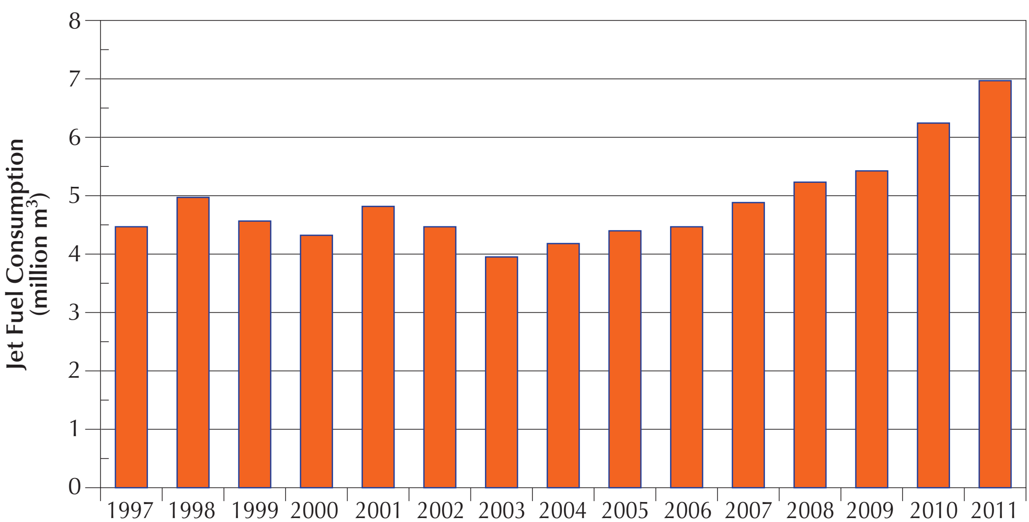

Figure 13 Jet Fuel Consumption in Brazil. Source: ANP apud Pinto Jr., 2012.

1. *ANP can contribute to the consistent planning of energy under the economic environmental and social aspects, in order to define the participation of alternative aviation fuels considering its positive externalities and the alternatives in R&D&I (new generation products begin to eclipse alternatives in the medium to longer-term);*
2. *ANP can reduce the asymmetric information: reliability for government actions and market and provide transparency data to new investors.*
3. *ANP fosters the entrance of new fuels fit for purpose in the market.*

World jet fuel demand is the fastest growing fuel globally in the last 20 years, and is projected to grow 1.8% annually. Global market for jet-A fuels in 2011 was 5.3 million barrels per day, expecting to reach in 6.4 million bpd in 2020 and 7.5 million bpd in 2030 (FAVELA, 2012).

3.2 The Bioenergy Industry in Brazil

According to Brasil (2007), bioenergy[4] in the Brazilian energy matrix is mainly composed by sugarcane products (ethyl alcohol and bagasse), wood products (firewood and charcoal) and responds for about 36.9% of primary energy production, being sugarcane products 16.9% and wood products 10.3% (Brasil, 2007).

Sugarcane products are basically ethyl alcohol 4.6% (basically used as light vehicle fuel), sugarcane bagasse 11.1% (basically used to power sugar factories and ethanol distilleries). Wood products are firewood 6.6% (used as fuel in industry, and residences), and charcoal 2.0% (basically used in industry and residences). The total amount of bioenergy used in Brazil in 2011 was 65,482,000 toe (tonnes of oil equivalent).

In 2011, biomass consumption in Brazil was used in the following sectors: energy sector 15.9%, residential 10.7%, commercial and public 0.3%, agriculture and livestock 3.7%, transportation 16.4%, industrial 53% (cement 0.6%, pig iron and steel 5.8%, iron alloys 0.9%, chemical 0.2%, food and beverages 29.3%, textiles 0.1%, paper and pulp 10.9%, ceramics 3.7%, others 1.4%).

Analyzing these figures it can be concluded that Brazilian economy, not only the transportation sector, is highly dependent of various types of bioenergy. Basically it can be stated that biomass used in Brazil for energy purposes are essentially used for ground transport, electricity production, and biomass power plant demand. In none of these sectors there exists limiting important factors, such as availability of land or competition with food, affecting biomass supply (CORTEZ, 2010).

However, the two main established sectors in Brazil regarding liquid biofuels are the sugarcane sugar-ethanol and the soybean biodiesel.

The ethanol program was initiated in 1975 after the first oil crisis that severely hit the country situation given that oil imports (80% of total consumed) represented 50% of all imports. Since then, the trajectory of the Brazilian sugarcane sugar-ethanol sector was quite

4 The term "bioenergy" is broader than biofuels because it includes other forms of energy from biomass, such as bioelectricity, which is the electricity generated from bio derived products.

impressive both by its contribution to alleviate oil dependence and also to improve sugar exports and promote rural development. In 2011, sugarcane ethanol responded for roughly 1/3rd of the energy consumption by vehicles powered by spark-ignited engines and sugarcane supplied 17% of all primary energy in the country.

According to UNICA (JANK, 2012) the sugarcane sector is established in 430 mills, comprising 70,000 growers, employing around 1.2 million workers, with a total revenue of US$ 48 billion and annual exports of US$ 15 billion. Brazil today is the 1st sugar producer in the world, responding by 25% of world production and 50% of world trade. As far as ethanol, Brazil is the 2nd ethanol producer in the world, responding by 20% of world production and 20% of world trade.

Sugarcane is cultivated in about 9 million ha in Brazil, only around 1% of Brazilian territory. It is currently used to produce food (sugar), fuel (ethanol), bioelectricity and plastics, but it can also serve as a base for drop-in jet fuels if science and technology advancements are made, as well as the right scenario is in place for funding, taxes, regulation and logistics, among others.

In the last decade the sector has gone through a strong consolidation process, as presented by Jank (2012). According to UNICA, the higher concentration increases competitiveness due to economies of scale and scope. Also UNICA understands that despite the recent merging & acquisitions the industry remains fragmented. **Figure 14** illustrates the sector consolidation.

Figure 14 Consolidation process experienced by the Brazilian sugarcane sugar-ethanol industry in the last decade. Source: Jank, 2012.

Another very important biofuel emerging sector in Brazil is biodiesel. The Brazilian biodiesel program (PNPB – Biodiesel Production and Use Program) was launched in 2004 mainly motivated to reduce diesel consumption which is still high comparing to other oil derivatives. The Brazilian Federal Government also wanted to combine energy goals with policies to reduce poverty in rural areas. Therefore the program favored several crops that could be cultivated by families and in regions of the Brazilian Northeast (BRASIL, 2004; NOGUEIRA; CAPAZ, 2013).

A series of measures were taken to implement the program, including a mandatory initial 2% blend of biodiesel in diesel, a "social stamp" characterizing the production by Family agriculture, and BNDES financing. As a result the biodiesel production capacity in Brazil grew fast (**Figure 15**) reaching 6.8 billion liters in 2012, according to Beltrão (2012). Worth mentioning that, up to now, Brazil does not have any established policy to increase the mandatory amount of biodiesel in diesel above 5%.

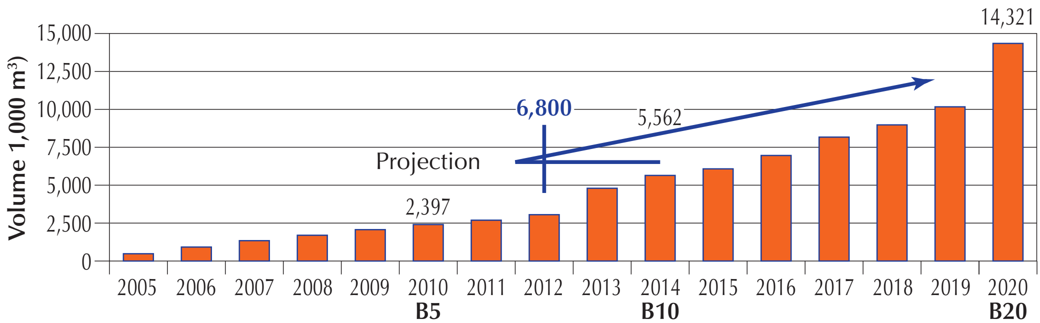

Figure 15 Biodiesel production capacity in Brazil.
Source: UBRABIO apud Beltrão, 2012.

Nevertheless, the dynamism presented in growing production capacity was not accompanied by the increase in biodiesel production. Reasons are the lack of competitive prices with diesel to operate on a free market and reliance on the mandatory blend, nowadays 5%, in diesel. In 2012, around 80% of biodiesel in Brazil was produced using soybean and about 15% from beef lard. The complement is obtained from other oil seeds such as cotton seeds. In the next decade it is expected to have an important growth in biodiesel production in Brazil and also the participation from other feedstocks. **Figure 16** illustrates this trend.

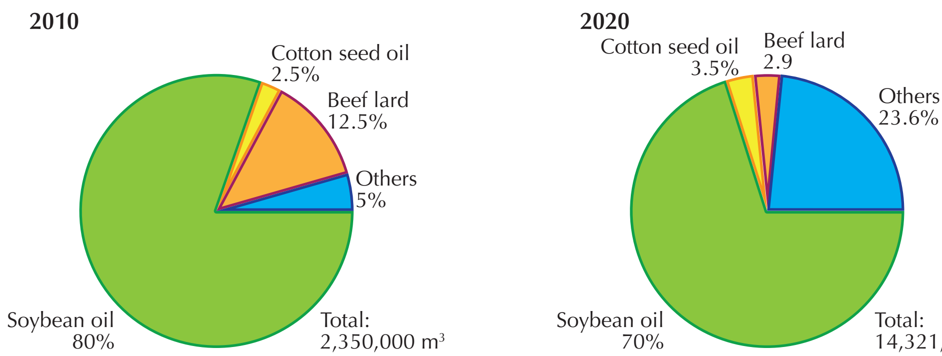

Figure 16 Expected biodiesel production in Brazil and feedstocks.
Source: adapted from UBRABIO apud Beltrão, 2012.

The perspective of introducing biofuels for Brazilian aviation creates opportunities for the new (upstream) bio-industry that will emerge to fulfill the requirements of the aviation industry. The existing liquid biofuels production and related infrastructure in Brazil is basically to produce sugarcane ethanol and biodiesel from different sources, mainly, soybean, lard, and other oilseeds.

The challenge imposed when biofuels for aviation are considered in Brazil involves a totally new set of measures from defining players, developing technologies, implementing logistics, rendering financial resources available, and deploying a constant and long term research effort to continuously improve biofuels for aviation continuous improvements.

Although the current state of knowledge on potential Brazilian feedstocks and technologies is considerable, it is probably insufficient considering the magnitude of problems involved in biofuels for aviation. The gaps and barriers were addressed in the workshops that took place in 2012 and are the object of this report.

3.3 Future industry: market trends and projections

This section presents market projections that may help define what the future market will probably demand. In other words, the purpose of this section is to provide an initial estimate of the market needs that must be fulfilled by the future scientific and technologic developments. A basic premise of any TRM process is that it is driven by market needs and not by the technology itself.

In Brazil, commercial aviation jet fuel demand is expected to raise both in quantity but also in its participation relatively to other fuels. Nigro (2012) has shown that in a "green scenario for 2020", where enough of biofuels would be available and applied to substitute fossil fuels in a compatible way with the Brazilian fleet on the roads in 2020, jet fuel participation would grow from its present 9% to 12% of CO_2 emissions from transport, if aviation biofuels are not used by then (**Figure 17**).

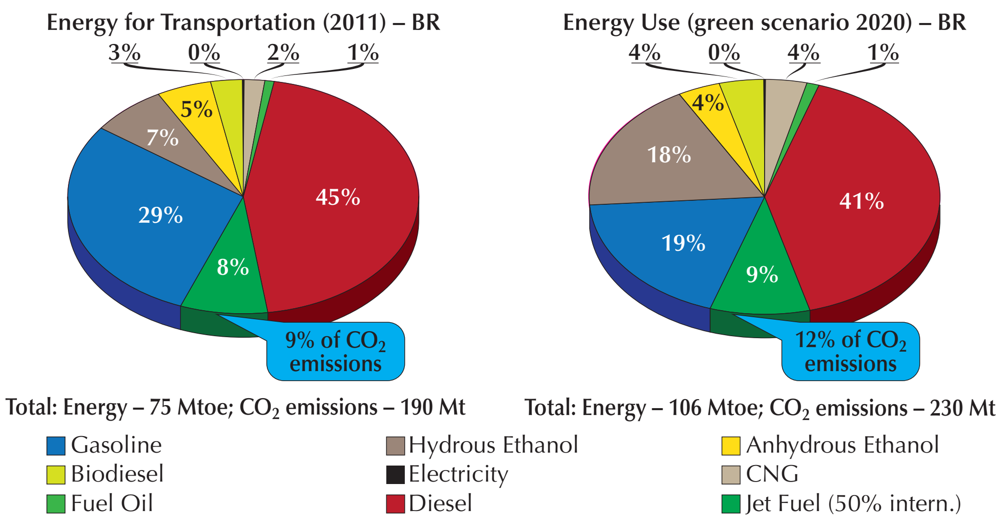

Figure 17 Biofuels for curbing CO_2 emissions from transport in Brazil. Source: Nigro, 2012.

Based on the same "green scenario for 2020" and admitting that the annual growth of jet fuel consumption, expected to be around 5%, was to be supplied by biofuels, in such a way that aviation in Brazil would experience a "Carbon Neutral Growth" without trading schemes outside the sector, the demand of biofuels for 2020 would be the ones presented in **Table 5**.

Table 5 Foreseen biofuels potential for 2020 in Brazil (Nigro, 2012).

BIOFUEL	SÃO PAULO	BRAZIL
Ethanol	19.8 billion liters	46.2 billion liters
Biodiesel	1.5 billion liters	6.2 billion liters
Biokerosene (5%)	0.2 billion liters	0.6 billion liters

According to Mcfarlane (2012) the aviation industry commitment to reduce carbon emissions is based on two-fold strategies: (a) using less fuel, by manufacturing more efficient airplanes and promoting operational improvements; (b) changing the fuel: sustainable biofuels.

Figure 18 shows the main R&D efforts to reduce CO_2 emissions and reduce noise footprint along the last decades.

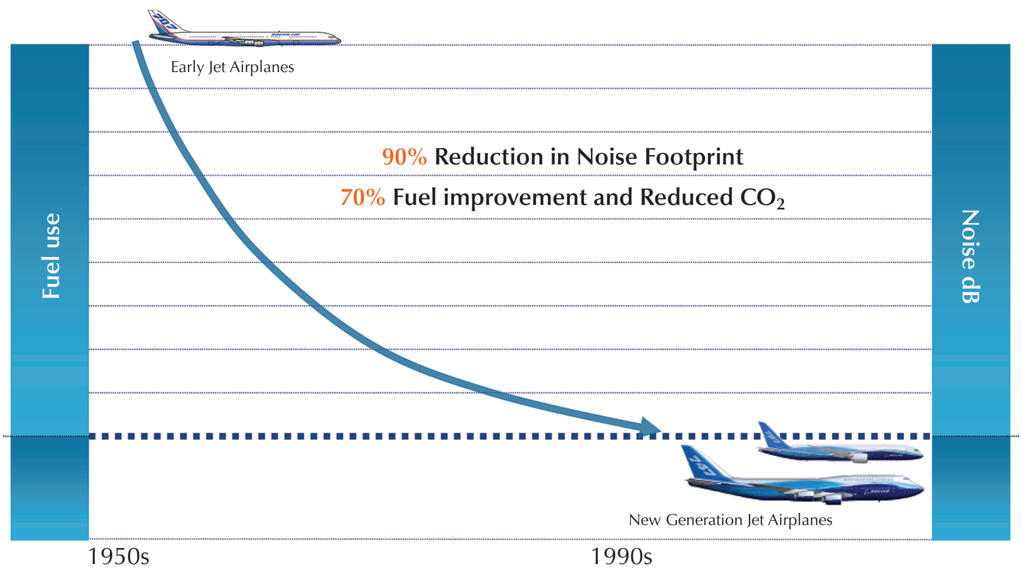

Figure18 History of environmental Progress in Commercial Aviation. Source: Boeing apud Macfarlane, 2012.

If no action is made by the aviation industry the global CO2 emissions derived from fuel burn of commercial flights will raise from about 600 million tons in 2011 to about 1200 million tons by 2050 (BOEING apud MACFARLANE, 2012).

The aviation industry is considering sustainable biomass as a priority feedstock for kerosene substitution. “Sustainable biofuels provide the only route with existing technology to put aviation on path to low carbon growth and economic and environmental sustainability” (MACFARLANE, 2012). Therefore, he concludes:

> ***“Aviation fuels should receive priority consideration for development of fuels from available sustainable feedstocks”***

Therefore, having recognized that fossil kerosene needs to be replaced by sustainable biofuels, the aviation industry has produced possible scenarios, as presented schematically below (**Figure 19**). One should observe that market based measures, like for instance the possibility of acquisition of carbon credits from other sectors by the airlines, are represented by the red triangle in the middle of this figure, on a hypothetical manner.

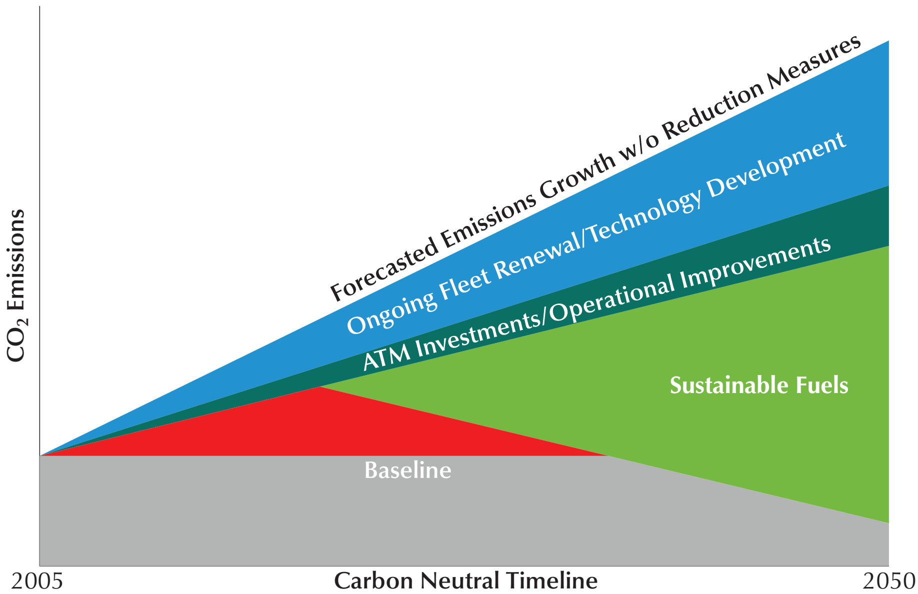

Figure 19 Aviation actions to reduce CO_2. Source: Boeing apud Lyons, 2012.

Another very important feature for the biofuels, besides the potential to mitigate GHG emissions, is related to its production costs. A special attention should be given in promoting sustainable but also **cost competitive biofuels for aviation**.

Competitive cost is considered a very important feature of jet fuels to allow the aviation industry worldwide expansion. However, the adoption of biofuels in aviation has brought a concern about that. **Figure 20** below shows how critical the impact of rising fuel prices has been in recent years and how important is the share of its costs in the overall breakdown of airline operating costs.

However, biofuels production costs from different sources are expected to decline in the coming future as the industry will learn as they will make larger volumes. **Figure 21** illustrates these possibilities from different biofuels.

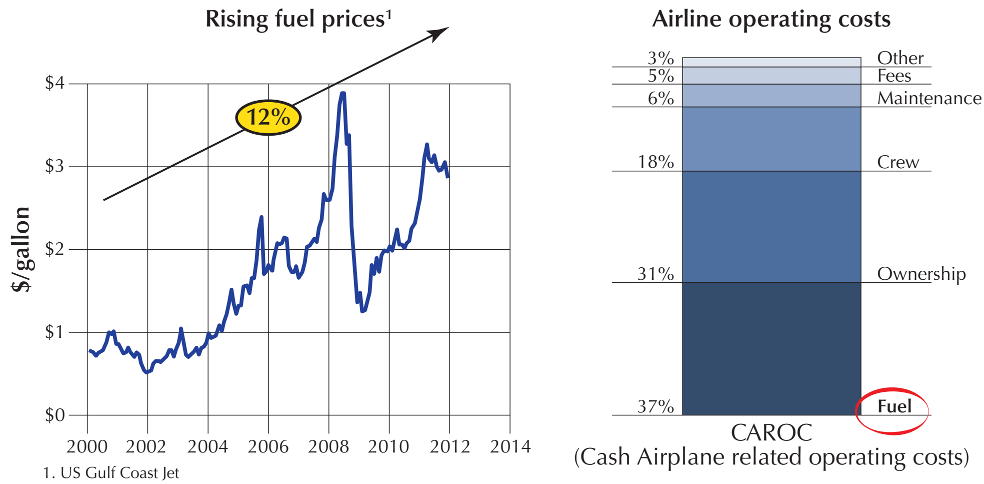

Figure 20 Recent rising of fuel prices and airline operating costs. Source: Boeing apud Lyons, 2012.

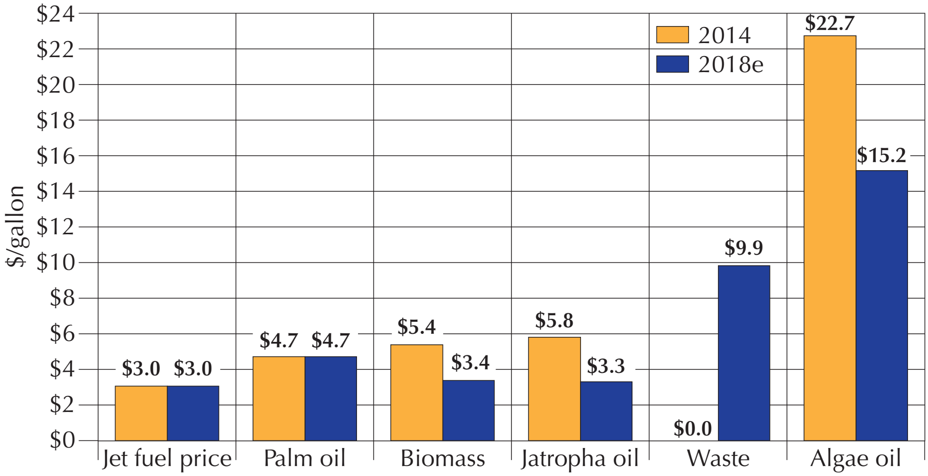

Figure 21 Cost of biofuel near (2014) and longer term (2018). Source: Boeing apud Lyons, 2012.

The demand of the aviation market for feedstocks to produce biofuels for aviation is expected to be very gradual. In order of magnitude this will be near 3 billion liters, therefore its supply should not represent any major concern, at least until 2020.

However, a more conclusive analysis is needed on how the aviation industry demand for biofuels will occur and how it will affect other sectors, even for a country such as Brazil. Growth scenarios from other sectors involving demand of land for food (including exports), for the production of biofuels for ground transportation are also needed so that there will be no shortage of feedstocks in Brazil.

Figure 22 below shows that the relative importance of sugarcane and wood products are expected to be maintained by 2030, meaning that there will be an important growth in supply of sugarcane products in the coming two decades in Brazil. However it is recommended that future demand of feedstocks for the production of aviation biofuels is well planned and with the participation of the private and public sectors, particularly the institutions related to financing productive investment.

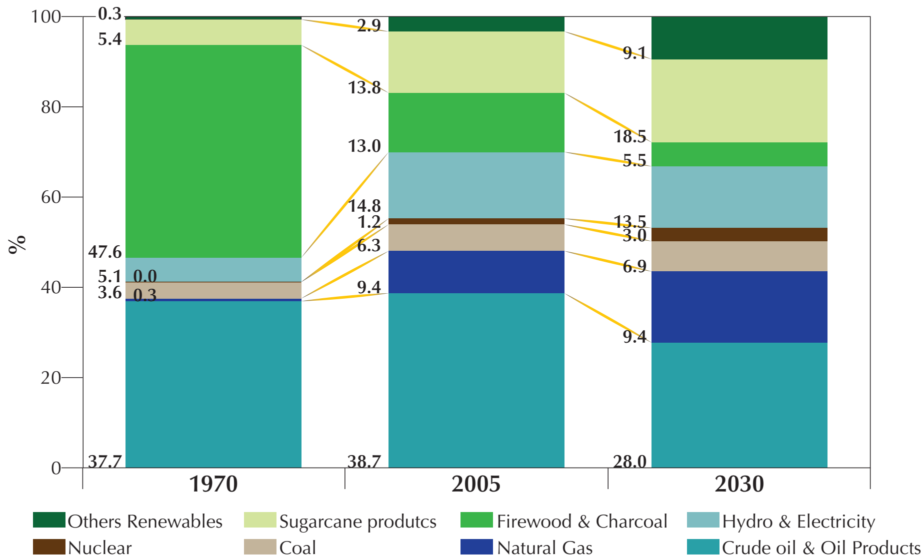

Figure 22 Expected Evolution of Energy Supply – Brazil.
Source: adapted from MME-EPE, 2007.

Considering necessary technical requirements to be achieved by aviation biofuels the aviation industry supports "drop-in" fuels that: (a) Meets fuel performance requirements; (b) Requires no change to airplanes or engines; (c) Requires no change to infrastructure; (d) Can be mixed or alternated with today´s Jet-A fuel (LYONS, 2012).

As far as the aviation industry goals, Boeing has set a goal that there will be enough global supply of sustainable aviation biofuel to address 1% aviation fuel by 2015 (~600 M gallons) in 3-5 large refineries, using 1.5 Mha of agriculture land with sustainable energy crops and near price parity with traditional jet-A. Regarding necessary actions, BOEING is developing core activities such as trying to create support and advocacy, helping to promote feedstock and pathway R&D, and obtaining fuels approval (LYONS, 2012).

Figure 23 below shows several BOEING collaborations can be mentioned worldwide to promote use of biofuels for aviation.

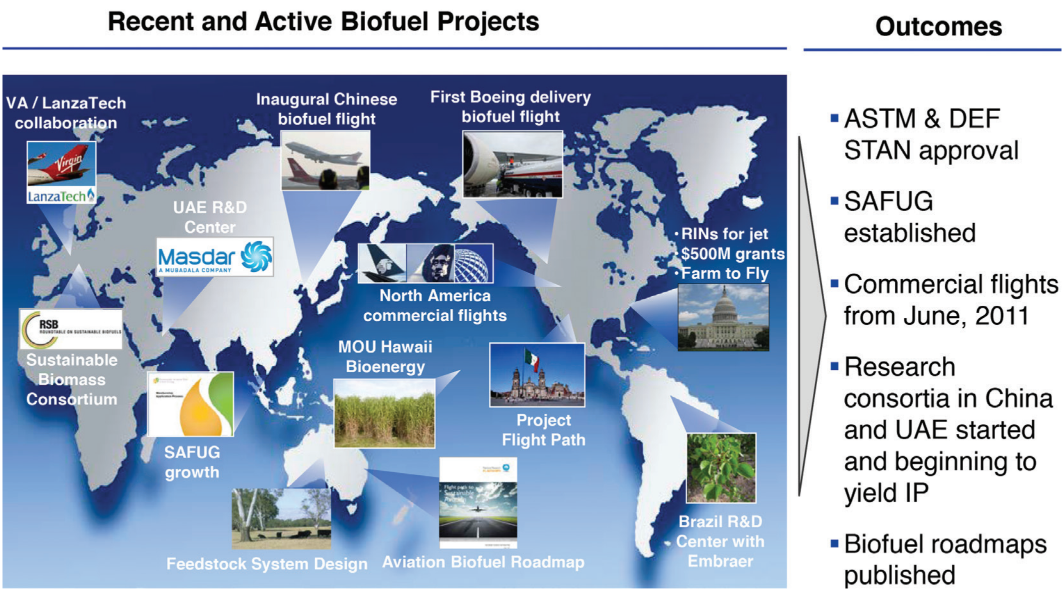

Figure 23 Boeing global biofuel engagements. Source: Boeing apud Lyons, 2012.

3.4 Relevant limiters

This section presents some of the most relevant limiters for the development of the aviation biofuel industry in the future. The points presented here were derived from the breakout session that took place in the 1st Workshop of the Sustainable Aviation Biofuels for Brazil Project, focusing on the previously established vision. The result is summarized below:

1. **Technological limitations**
    1. lack of technological alternatives (industrial processes and feedstocks);
    2. lack of investment in R&D for feedstocks and processes;
    3. availability of fuel efficient airplanes from 2015 and beyond;
    4. productivity of feedstocks (example: sugarcane);
2. **Infrastructure limitations**
    1. airport infrastructure and poor traffic management;
    2. transport, distribution and storage: general logistics gaps for fuels in Brazil;
3. **Sustainability related limitations**
    1. availability/expansion of production of feedstock and sustainability (social and environmental) issues related to agricultural feedstocks;
    2. certification: accelerates acceptance of biofuels for aviation, but may help or be a barrier to its development, depending on strictness of standards;
    3. competition with other uses of feedstock;
    4. civil society perception/public opinion;
4. **Policy limitations**
    1. lack of public policies to motivate investments on biofuels for aviation (development and adoption);

2. approval process of biofuels for aviation (similar to ASTM);
3. taxes;
4. low/stable price of gasoline in Brazil;

5. **Cost related limitations**
   1. costs of final product/competitiveness of fuel;
   2. cost of processing/technologies;
   3. feedstock costs (85% of the cost, in some cases);
   4. price volatility and supply risks (feedstocks);
   5. lack of financing alternatives.

Final considerations on TRM process

The authors of this report sought to present the context in which the technology roadmapping (TRM) was conducted. A long term vision for the aviation industry in Brazil has been presented, as well as the scope of this research project and its strategic goals. The report also described the current state of the industry, in terms of products, customers, producers, suppliers and processes, indicating probable market trends that will demand adaptations in those and also some relevant limiters to fulfill the long term vision.

This part of the roadmap report has a general purpose, which means that it sets the ground for the TRM process as a whole. It defines a vision, scope, and current state of the industry and future needs. The next chapters of this report will deal with each of the TRM components – Feedstock, Refining Technologies, Sustainability, R&D, Commercialization and Policies issues.

A series of 8 workshops was organized by the Sustainable Aviation Biofuels for Brazil Project in 2012 to identify the technological capabilities and needs of each TRM issue. Each workshop has addressed the following:

1. identify the “product” that the component will focus (i.e.: products and processes);
2. identify critical system requirements, its targets and how they should evolve in the time frame (horizon);
3. specify the large relevant technology areas that contribute to meet the critical system requirements, including current scientific and technological capabilities;
4. specify the technology drivers of each technology area and its targets in the time frame (horizon);
5. identify alternative technologies and their time frame (horizon);
6. recommend the technology alternatives to be followed;
7. identify R&D gaps and other important limiting factors.
8. briefing to stakeholders

The project team of the Sustainable Aviation Biofuels for Brazil Project has identified possible pathways which have been used to point the technology barriers and gaps.

The R&D and Commercialization Workshop summarized all R&D and limiting factors identified in the workshops, adding business aspects to the discussion. This assessment naturally depends on the focus or perspective from which the biofuel is being evaluated. For example, if the evaluation is being conducted for cost analysis, each step of production and distribution needs to be quantified. It is well known that, in general, the feedstock cost plays an important role in biofuels production. In case of sugarcane ethanol it can be close to 70% and in case of biodiesel up to 80 or 90%. Another perspective, actually the main objective of the Sustainable Aviation Biofuels for Brazil Project, is to analyze the proposed biofuel (feedstock and refining technology) from the CO_2 emissions perspective. In this case the entire LCA will need to be performed to analyze its GHG mitigation potential and where the main questions to be answered remain.

The Policy and Incentives Workshop proposed a set of policies to help develop an aviation biofuel industry based on sustainable biofuels. One of the essential parts of the present roadmap is the discussion, identification of gaps and challenges to be overcome. These gaps and challenges can be of S&T nature and also related to infra-structure, improve of human resources qualification, for example. From the workshops and discussions a set of policies have been defined to provide conditions so that biofuels for aviation can be produced, transported and distributed in a sustainable way, meaning also low cost for the final consumers.

The workshops have provided valuable information to develop scenarios/pathways, which were analyzed based on assessment of likely commercial feasibility in 2015-22 timeframe, and considering long term timeframe (2050). Each workshop gathered stakeholder perspectives and insights on prospective pathways. The specific workshops were:

Workshop	Venue	Date
1 - Project Overview	FAPESP, São Paulo, SP	April 25-26, 2012
2 - Feedstocks	ESALQ/USP, Piracicaba, SP	May 22-23, 2012
3 - Refining Technologies	FEQ/UNICAMP, Campinas, SP	July 11-12, 2012
4 - Sustainability	FIEMG, Belo Horizonte, MG	August 22-23, 2012
5 - Policy and Incentives	Embrapa Agroenergia, Brasília, DF	September 11-13, 2012
6 - Logistics & Support	ANP, Rio de Janeiro, RJ	October 17, 2012
7 - R&D and Commercialization Gaps	CTA, São José dos Campos, SP	November 28-29, 2012
8 - Briefing to Stakeholders	FAPESP, São Paulo, SP	December 12, 2012

A term of reference (ToR) was prepared by specialists from the Project research team in each of these topics covering technical and logistics difficulties and barriers, LCA, and where more research is needed.