Biomass Energy and Bio-energy Trade: Historic Developments in Brazil and Current Opportunities

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Abstract

Brazil has tradition on biomass production and use. The country fulfils the main required conditions regarding large-scale production of biomass, such as land availability, adequate weather conditions, inexistency of particular constraints regarding labour and the domain both of biomass-production and biomass-conversion technologies in the agricultural and in the industrial sides. This report describes the Brazilian experience on large-scale production of ethanol and on wood from planted forests (including for charcoal production). Brazilian experiences and perspectives on international biotrade are also addressed.

Introduction

Few countries with reasonable to good level of industrialization, like Brazil, have an energy matrix with such an important share of renewable energy sources. In 2004, 42 per cent of the Brazilian primary energy supply was covered by renewables. Hydraulic has contributed in 2004 with 12.8 per cent of the domestic energy supply. The set of biomass sources have covered in the same year 29.3 per cent of the domestic energy supply, with a contribution of 13.6 per cent of sugarcane products (alcohol and bagasse), 13.0 per cent of wood (firewood and charcoal) and 2.7 per cent of other renewable energy sources – mainly black liquor and

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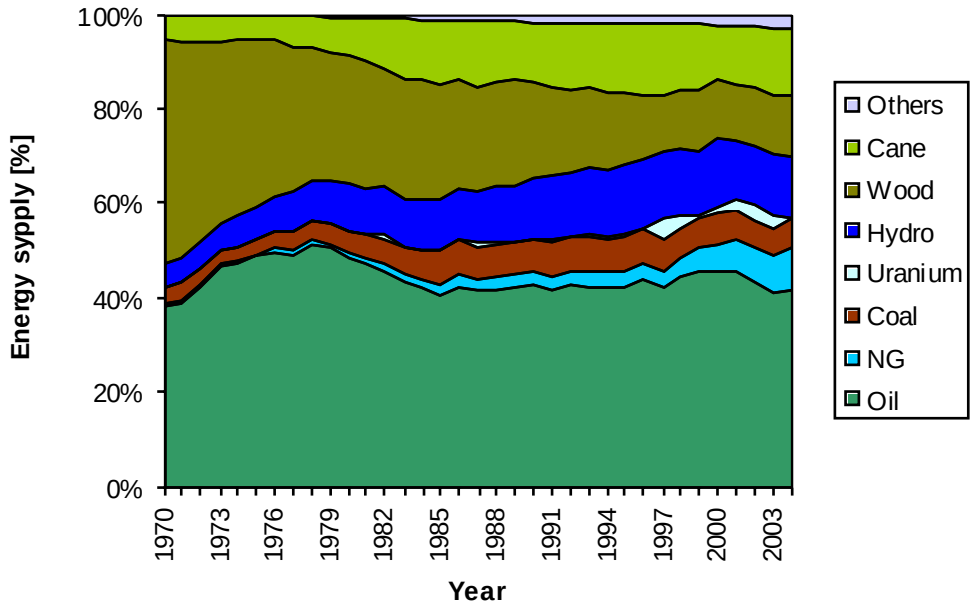
agricultural wastes. Figure 1 shows the evolution of the Brazilian energy matrix in the 1970-2004 period.



Source: MME (2005)

Figure 1. Energy matrix in Brazil – 1970-2004

As can be seen in Figure 1, the share of renewable energy sources has declined since mid-1980s. However, after 2001 a slight inversion has been observed in this tendency. Biomass contribution has also declined during the last 30 years – from 53.2 to 29.3 per cent – despite the creation of official programs aiming at support large-scale ethanol production and the use of charcoal to displace coal and coke consumption in steel mills[2]. Until mid-1980s the tendency was strongly influenced by the reduction of non-commercial wood consumption by households. On the other hand, from late 1980s onwards these tendencies were influenced by the partial failure of charcoal production program and the evolution of the ethanol program.

Brazil has tradition and a significant potential on biomass production. The historical importance of biomass energy in Brazil is due to a set of factors, including (i) the size of the country and the availability of land, (ii) the adequacy of its weather, (iii) the availability and the low cost of the working force and, most important, (iv) the domain of biomass-production and biomass-conversion technologies in the agricultural and in the industrial sectors. The

[2] As presented in this report, Brazilian Government has created these programs during the 1970s and 1980s aiming at reduce energy imports.

accomplishment of these conditions defines a potential biomass producer country in a bio-energy trade scenario.

The Brazilian experience in biofuels production indicates that it is possible to produce such fuels in a sustainable way and at a low cost. Taking into account the steady reduction of production cost, as happened in the case of Brazilian ethanol – as further presented –, biofuels could be commercialised worldwide, contributing to the reduction of carbon emissions with low economic impacts. The Brazilian experience can also be transferred to other developing countries, enabling them to enhance their energy supply with locally produced fuels. In medium-term, some countries could become biofuels exporters, indeed.

The following text presents some notes on the Brazilian experience and perspectives of large-scale production of ethanol and wood products (including charcoal production).

Part I – Ethanol

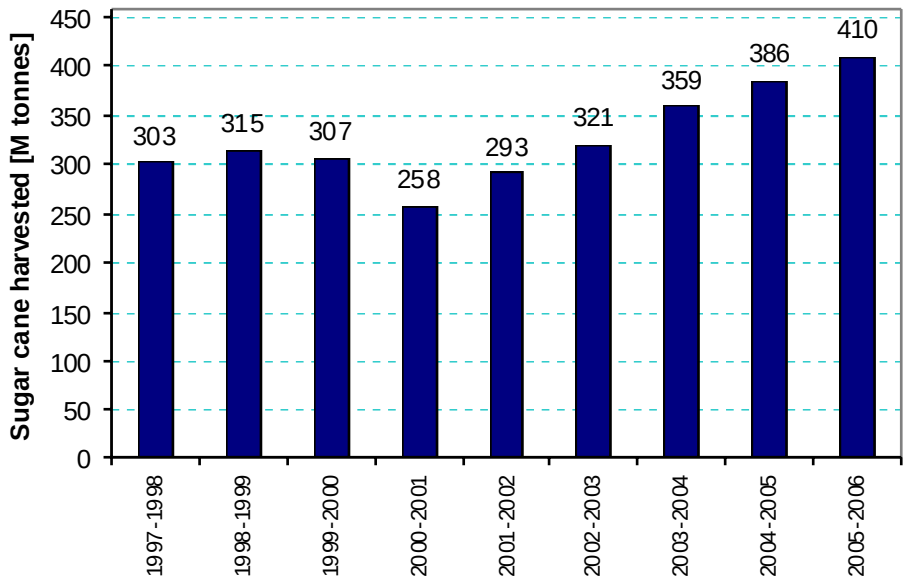
I.1 Ethanol production

Worldwide Brazil is the largest producer of sugarcane. It is estimated that the production in the last harvest season (2005-2006) has reached 410 million tons. As can be seen is Figure 2, the sugarcane production has risen during the last 5 harvest seasons (on average 9.7% per year).

The importance of this economic activity has grown after the creation of the Brazilian Alcohol Program – PROALCOOL – in 1975, with the purpose of producing anhydrous ethanol to be blended with gasoline. In mid-1970s Brazil was strongly dependent on imported oil and, at that time, gasoline was the main oil derivative[3]. The creation of PROALCOOL was also influenced by frequent problems faced by sugarcane entrepreneurs due to the excess of sugar production and strong variations of its international prices. More than 30 years after its

[3] In that year, imports represented 80% of oil consumption and gasoline production represented 25% of the derivatives production.

creation, PROALCOOL is still considered the largest biomass commercial program in the world[4].



Source: Szwarc (2004) and UNICA (2006)

Figure 2. Sugarcane production in Brazil

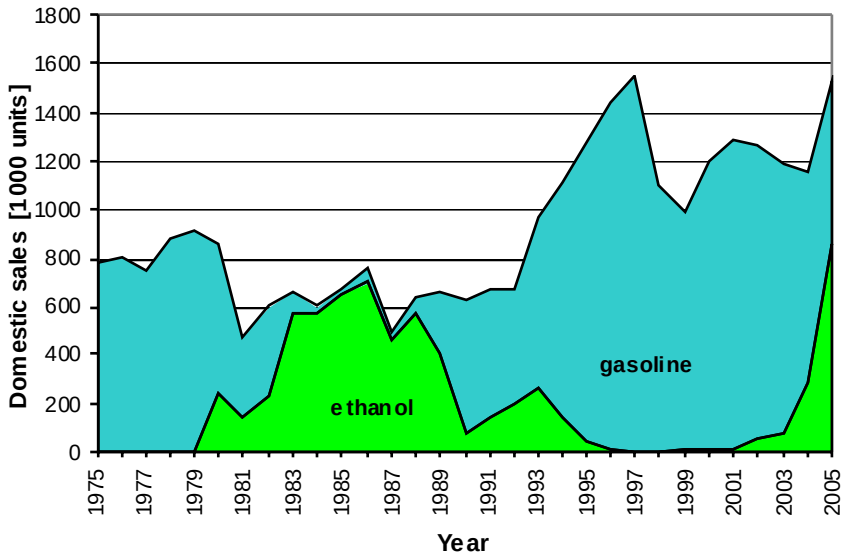
During the second oil chock, in 1979, Brazilian Government has decided to enlarge the Program, supporting large-scale production of hydrated ethanol to be used as neat fuel. During the so-called first phase of PROALCOOL (1975-1979) ethanol production was accomplished by new distilleries annexed to the existing sugar mills, while during the early years of the second phase (1979-1985) many autonomous distilleries were built. It is estimated that about US$ 11-12 billion were invested to create a structure able to produce 16 billion litres of ethanol per year. On the other hand, the savings regarding avoided oil imports were estimated as US$ 52.1 billion (January 2003 US$) from 1975 to 2002 (Goldemberg *et al.*, 2004).

Despite the success of PROALCOOL along its first ten years, during the third phase of the Program (1985-1990) oppositions were reinforced due to the decline of international oil prices

[4] Many authors state that the PROALCOOL no longer exists. For them, the Program was concerned with the Government action on regulation, production control and support to producers. Ethanol production was completely deregulated in late 1990s.

and to the heavy subsidies given to inefficient ethanol producers. Furthermore, despite efforts towards restructuring of oil refineries, large surplus of gasoline existed at that time.

The decline of PROALCOOL during the 1990s has started with an ethanol supply shortage in 1991 that deeply impacted the supplier's credibility, leading to a drop in sales of neat ethanol cars. Sales of pure alcohol vehicles that have reached 92-96 per cent during the eighties were continuously reduced until summing up just about 1,000 new vehicles per year in 1997-1998 (see Figure 3).



Source: ANFAVEA (2006) and Carvalho (2005)

Figure 3. Sales of cars and light commercials in Brazil

However, since 2001, due to a larger price difference between ethanol and gasoline, sales of neat ethanol cars have risen again. Recently, after the advent of flex-fuel vehicles – FFVs – in 2003, there is a boom on sales of vehicles able to run powered by ethanol. Regarding neat ethanol vehicles, the greatest advantage of the FFVs is that these motors can operate with regular gasoline – in case bio-fuels are not available or are not economically competitive (Coelho and Walter, 2006). In early 2005 the sales of FFVs surpassed the sales of gasoline cars and along the same year the sales of FFVs represented 57% of total sales. Some analysts predicted that in some years 90 per cent of the sales of new vehicles would be flex-fuel ones (Carvalho, 2005). As consequence, FFVs can represent 30-40 per cent of the Brazilian fleet by 2010.

It is clear that ethanol production in Brazil has started a new momentum with the arrival of flex-fuel vehicles in the market. In the ethanol production regions, and during most of the year, ethanol costs less than 60 per cent of gasoline (per litre) at service stations, and with such low prices ethanol consumption is rising remarkably.

However, due to the lower sales during the 1990s, neat ethanol fleet has been sharply reduced. By now the neat ethanol fleet is estimated as 2-2.5 million vehicles[5] regarding a peak of almost 5 million units at early 1990s. As consequence, during the 1990s ethanol production has been gradually shifted towards anhydrous ethanol, as can be seen in Figure 5. On the other hand, since 2001 the production of hydrated ethanol is increasing again. Flex-fuel vehicles can be filled-in with hydrated ethanol regardless of the amount of gasoline in the fuel tank.

Figure 4 shows the evolution of ethanol production from 1970 to 2005. The arrow indicates the year 1997, when deregulation of ethanol industry has started. After that, federal government has no longer influenced ethanol and sugarcane prices, subsidies have been phased-out and there is not any government intervention on ethanol sales. On the other hand, it is still in force the regulation regarding blend of anhydrous ethanol in gasoline, being ethanol percentages defined according to the balance between its demand and supply. The ethanol share in the fuel blend can vary from 18 to 26 per cent. In early 2006, the share of anhydrous ethanol in fuel blend was reduced from 25 to 20 per cent due to the high consumption of ethanol by flex-fuel vehicles.

Besides the rise of ethanol domestic demand, other factors are pushing the growth of sugarcane industry in Brazil, such as: (i) high demand for sugar both in the domestic and international market, (ii) the rise of ethanol exports and (iii) the continuous improvements in productivity[6]. Currently, Brazil has around 320 combined sugar mills and ethanol distilleries with a further 51 under construction[7], including new plants and expansion of existing ones. The ethanol production capacity was estimated as 18 billion litres in 2005. Technology development and cost reduction on ethanol production are analysed in the following section.

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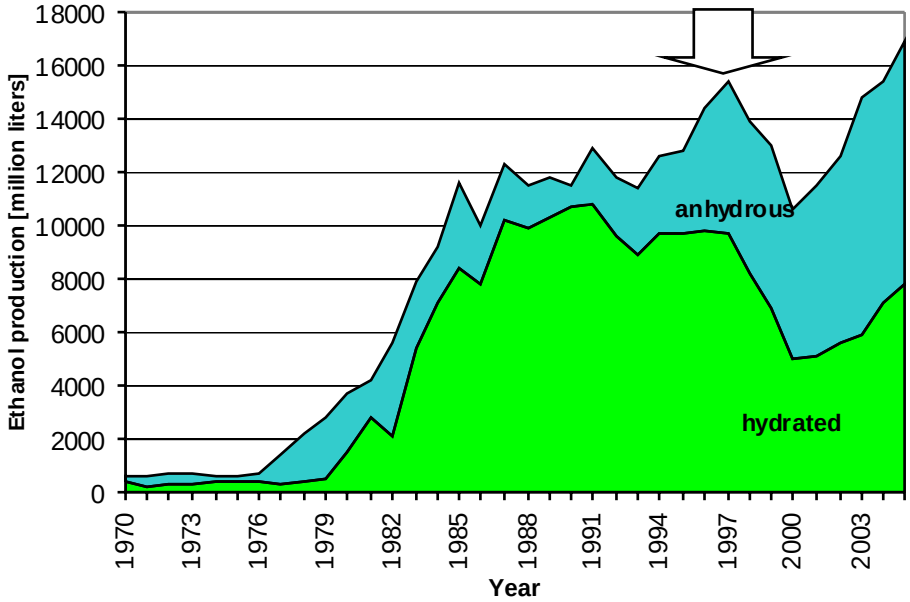
[5] The total fleet of cars and light commercial vehicles is estimated as 18 million

[6] Brazil is the most efficient producer of both sugar and ethanol, and hence has the lower producing costs.

[7] This includes large improvement in existing mills and new mill/distilleries which are also taken place in other states with less tradition of sugarcane and ethanol production, e.g., Mato Grosso, Goiás, etc.



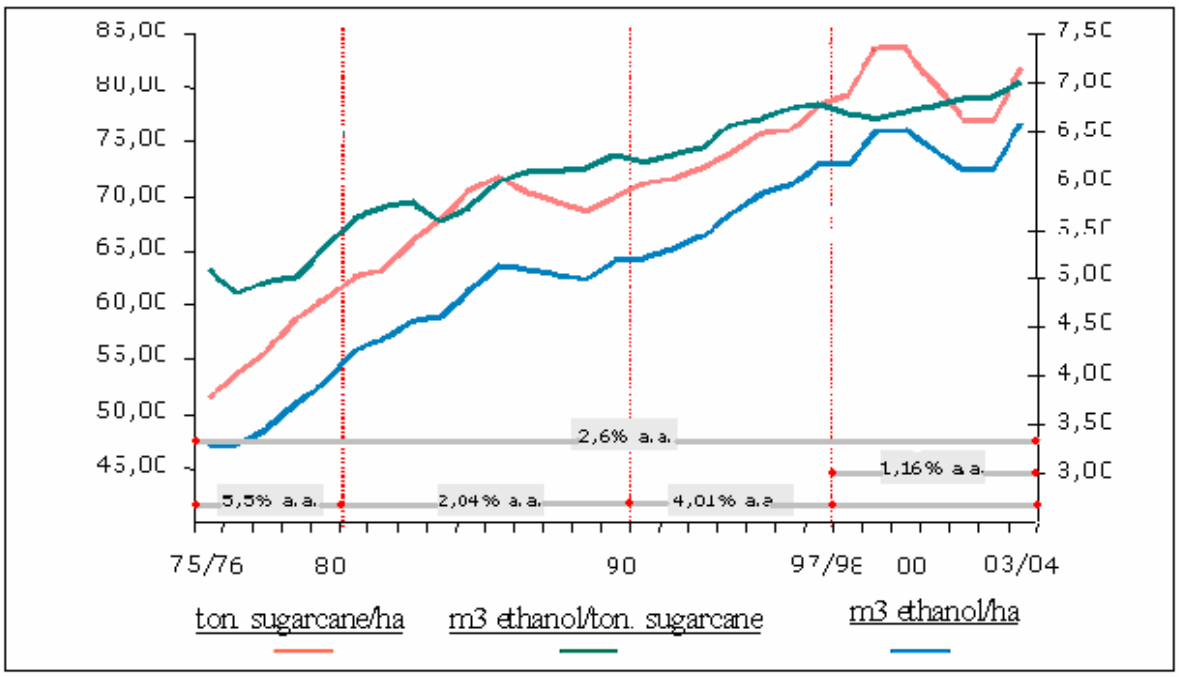
Source: MME (2005), MAPA (2006) and Nastari (2005a)

Figure 4. Ethanol production in Brazil 1970-2005

I.2 Ethanol – technology development and cost reduction

One important aspect of sugarcane industry in Brazil is that since the 1990s producers have explored a strategy to induce more flexibility into the industry, shifting the production to ethanol or sugar according to market opportunities. This has been possible due, at one hand, to the high competitiveness of Brazilian producers in the international sugar market. During the 1990s, when market was favourable for sugar exports, Brazil has even imported alcohol to match the fuel demand (see Figure 7 further on). It is also estimated that this strategy has led to some reduction on ethanol production costs.

Due to innovations both on the agriculture and on the industry sides, productivity has been improved and costs have fallen. To give a figure of comparison it should be noticed that average production yields were 3,900 year/ha/year in early 1980s and have reached 5,600 litres/ha.year in 2001 (Cortez *et al.* 2002). As can be seen in Figure 5, in Southeast Brazil this figure is even higher, reaching 6,500 year/ha/year (6.5 m^3 ethanol/ha). In Figure 6 it is also shown the average rates of improvement on productivity that reaches 2.6% per year since 1975.



Source: Carvalho (2004)

Figure 5. Sugarcane productivity in Southeast Brazil

Productivity improvements were mainly due to a significant increase in agricultural yield, which is a function of soil quality, weather conditions and agricultural practices, and also is strongly influenced by agricultural management. In late 1990s, the average productivity in Brazil was around 65 ton/ha (Moreira and Goldemberg, 1999) but can be as high as 100-110 ton/ha in the State of São Paulo[8] (Braunbeck *et al.*, 1999). However, yield figures should not be strictly compared with other countries, as sugarcane cultivation in Brazil is not irrigated. Yields have grown about 33 per cent in São Paulo State since the beginning of the ethanol program, mainly due to the development of new species and the improvement of agricultural practices (Macedo *et al.*, 2004).

Productivity gains – and, consequently, cost reductions – were also achieved as a result of the introduction of operation research techniques in agricultural management and the use of satellite images for species identification in cultivated areas. Similar decision-making tools have been applied in relation to harvesting, planting and application rates for herbicides and fertilizers (Coelho and Walter, 2006).

[8] Where 60-65 per cent of sugarcane production is concentrated.

Regarding ethanol costs, it was estimated in 2001 that the production cost of one litre of hydrated ethanol in mills of good productivity was 0.45 R$ (FIPE, 2001). At that time, for a currency exchange rate of 2.5 R$/1 US$, this cost would be equivalent to 0.18 US$/litre[9]. Just the widespread adoption of yet existing – and commercial – technologies would result in a reduction of ethanol production costs of about 13 per cent in the next 5-6 years, i.e., to about 0.15-0.16 US$/litre. However, by the end of 2005, due to the recent valorisation of Brazilian currency, the average cost of ethanol production in Brazil was estimated as 0.23 US$/litre (Nastari, 2005b). Considering this average cost, hydrated ethanol is competitive with gasoline as long as oil prices are down to 36 US$/barrel.

The tendency on cost reduction since 1980 can be observed in Figure 6, where the "learning curve" for ethanol production in Brazil is shown (Goldemberg *et al.*, 2004). This curve, as proxy, is based on prices paid to producers. As shown, the progress ratio in the 1985-2002 period is estimated as 0.71, while the progress ratio in the 1980-1985 period is estimated as 0.93.

I.3 International market for ethanol

There is some optimism regarding the enlargement of the ethanol market as some countries are interested to start to use (or effectively are yet using) ethanol-gasoline blends. The interest is motivated by a set of factors, including (i) the rise of oil prices, (ii) the convenience of reducing oil dependence, (iii) the necessity of reducing air emissions in large cities, (iv) the necessity of accomplishing targets defined by Kyoto Protocol and (v) the necessity of abolition of MTBE as octane enhancer. Just in the United States, the phase out of MTBE use[10] would correspond in the short-term to a market enlargement of 6 billion year/year. In many countries[11] the interest is due to a combination of socio-economic issues (e.g., supporting agricultural activity) and environmental issues (e.g., reducing local and global impacts).

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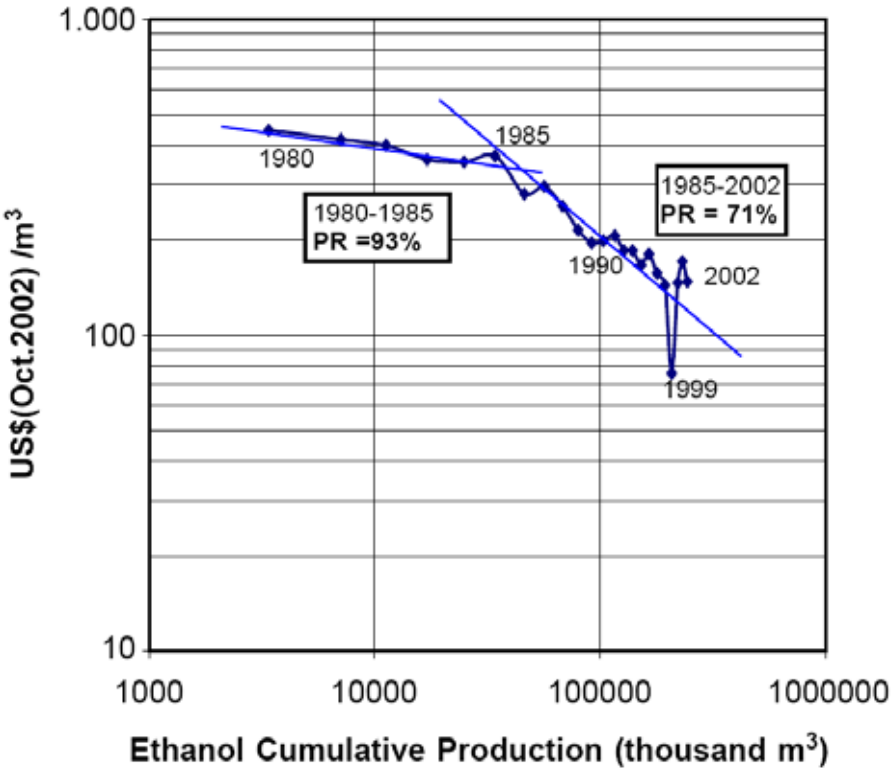
[9] Raw material, i.e., the sugarcane itself, represents about 70 per cent of the ethanol cost. In March 2006, the currency exchange rate was 2.20 R$/US$.

[10] In 2003, in California, and in 2004 in the East Coast states.

[11] As, for instance, Canada, Australia, India, China and in the European Union.



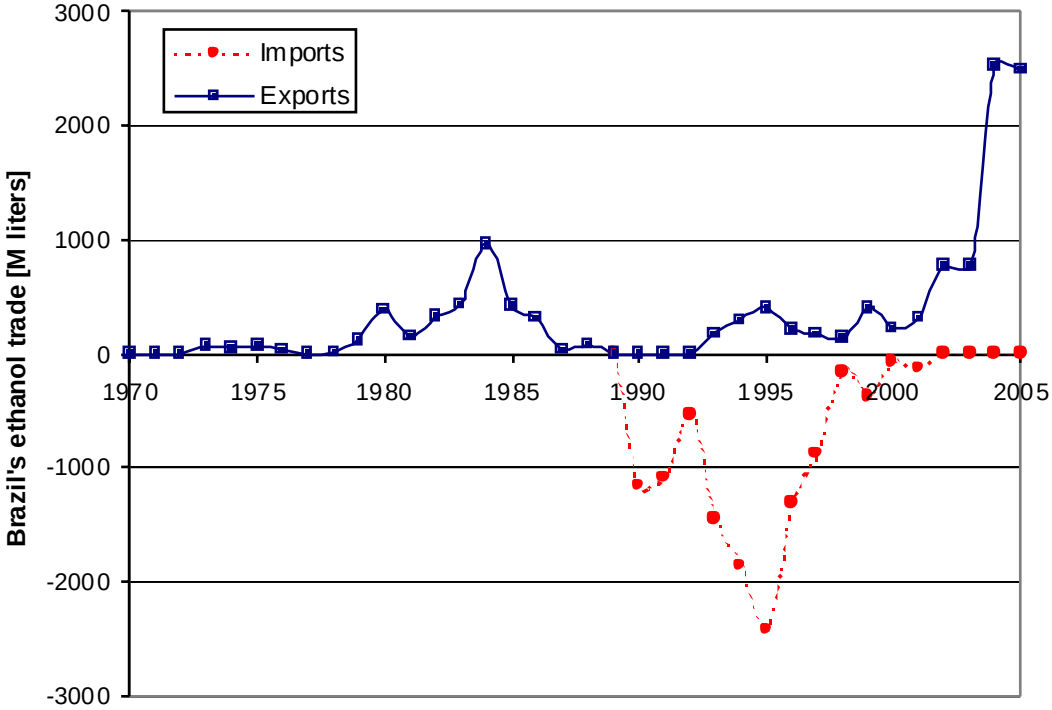
Source: Goldemberg *et al.* (2004)

Figure 6. Learning curve for ethanol production

Many countries have implemented "agro-energy" policies due to energy supply concerns. However, in some cases the motivation has also resulted from environmental-based initiatives, such the EU Biofuels Directive and the USA Oxygenated Fuels Program. Some countries have recently expanded existing domestic fuel-ethanol production programs (e.g., Brazil and USA) or started new ones (e.g., Canada, Colombia and Peru). In fact, more than 30 countries already have introduced or are interested in introducing fuel ethanol programs of some source, but currently world production and consumption is dominated by Brazil and the USA, which are responsible for 70% of world production. Nevertheless, despite of favourable conditions to bio-energy expansion, fuel-ethanol still plays a minor role in the energy market, as it represents just about 2.5% of the current gasoline consumption.

Figure 7 shows Brazil's ethanol trade since 1970. Market opportunities and constraints have determined exports and imports. An expressive amount of alcohol was imported during the 1990s, first during the supply shortage of ethanol (1990-1991) and, after, when international sugar markets were favourable for exports (1993-1997). Traditionally, Brazilian exports of ethanol have been oriented for beverage production and industrial purposes but, recently,

trade for fuel purposes has enlarged. As can be seen in Figure 7, after 2000 Brazilian exports of ethanol have risen steadily. In 2004 exports reached 2.5 billion litres and it is estimated that almost the same amount was exported in 2005.



Source: MME (2005) and (Nastari, 2004)

Figure 7. Brazilian exports of ethanol

In 2004 the main destinations of Brazilian exports of ethanol were India (23.1%), US (20.2%), South Korea (10.2%), Japan (9.2%), Sweden (8%), Jamaica (6.3%), The Netherlands (6.2%), Mexico (3.5%) and Costa Rica (3.2%). In the case of Caribbean and Central American countries, most of the final destination was in fact the US market. The Caribbean Basin Initiative – CBI allows imports from these countries with no duties up to 7% of the US market. Early 2006, the main exporters were United States and Japan.

The USA has the world's fastest growing fuel ethanol market. The installed capacity in 2004 was approximately 14 billion/litres, while the production in the same year was estimated as 13 billion/litres. In USA the main feedstock is corn, but many other feedstock are used. The phasing out of MTBE as octane enhancer, motivated by continued concerns about water contamination, is the main reason for the rapid growth of the fuel ethanol market. In 2003 ethanol began to replace MTBE in California, New York and Connecticut and by the end of

2005 more than 20 states are expected to phase out MTBE. In addition, the market in USA can reach 19 B/l/yr by 2012 due to the recent approval of Renewable Fuel Standard (RFS) by the Federal Congress. Despite the large ethanol production, USA should not be an exporter in the international fuel-ethanol market due to their high production costs and the large domestic demand (Rosillo-Calle and Walter, 2006).

Table 1 presents estimates of ethanol markets in 2010. Conversely, Table 2 presents market estimates for exports; in the case of USA the market for international trade is evaluated as just 1.2 billion litres in 2010 (through CBI scheme).

Table 1. Estimated ethanol markets in 2010

Country/Region	Ethanol market [billion litres]
United States	18-20
Europe (EU)	9-14
Japan	10
South Korea	1.9
China	4.8
Eastern Europe	1-2
Canada	1-2
Total, including Brazil and other countries	50-70

In Europe, a directive obliges the use of certain amount of renewables in automotive fuels (e.g., 2% in 2005 and 5.75% in 2010) and, as consequence, the potential demand in 2010 (EU-25) is estimated as up to 14 billion litres. The demand can be accomplished by internal production, but it is important to notice that production costs are almost 3 times higher than in Brazil. European market is nowadays highly protected as well. European market for exports is evaluated as up to 3 billion litres in 2010. On the other hand, Japan is considering the use of ethanol-gasoline blends to reduce GHG emissions. Nowadays E3 (3% ethanol – volume basis – in the blend) is not mandatory. Considering a possible target of E10, the market is estimated as 10 billion litres is 2010. Japan cannot be an ethanol producer and all ethanol should be imported (Rosillo-Calle and Walter, 2006).

Table 2. Potential markets for ethanol exports [million litres]

Country/region	2005	2010
United States (through CBI)	600	1,200
Europe (EU)	1,000	3,000
Japan	500	6,000
South Korea		1,900
China		2,300
India	600	1,500
Canada	400	600
Thailand	700	1,000
Total	3,800	17,500

The world fuel-ethanol market is in its initial stage and is not yet well structured. Protectionist barriers that exist in important energy markets (e.g., EU and USA) limit its evolution and inhibit its consolidation. As defend those who claim for economy liberalization, total domestic market protection is negative to technological development, to the enhancement of productivity and also to cost reductions (Piacente and Walter, 2005). According to Carvalho (2005) three principles should guide fuel-ethanol international market: (i) fuel-ethanol import prohibition – or limitation – should be substituted by agreements which would allow imports under more flexible conditions; (ii) fuel-ethanol import tariffs should be lower than those applied to oil derivatives, due to environmental benefits of the product; and (iii) subsidies should be progressively phased-out in order to promote production efficiency and fair market competitiveness.

I.4 Expansion of sugarcane sector in Brazil

Since 1975, crushing of sugarcane has risen from 91.5 (1975/76) to more than 400 million tons (2005/06) (i.e., about 350%), while the production of sugar and ethanol measured in sucrose equivalent have risen from 7.30 to 55.1 million tons (655%). Just since the year 2000 sucrose supply has risen 11.1% per year. The perspectives for ethanol and sugar production in Brazil up to 2010 and 2015 are summarized in Table 3. In 2005, the estimates are that the sugar production has reached 28 Mt (10.9 Mt for the domestic market and 17.1 Mt for exports) while ethanol production has reached 16.8 Bl (14.3 Bl for the domestic market and 2.5 Bl for exports).

Table 3: Estimates for 2010 and 2015 – Brazil

Production and markets	2010	2015
Sugar – domestic market [Mt]	12.1	13.3
Sugar – exports [Mt]	20.6	23.6
Sugar – total production [Mt]	32.7	36.9
Ethanol – domestic market [Bl]	21.0	28.7
Ethanol – exports [Bl]	5.0	6.0
Ethanol – total production [Bl]	26.0	34.7
Sugarcane production [Mt]	560.0	696.0

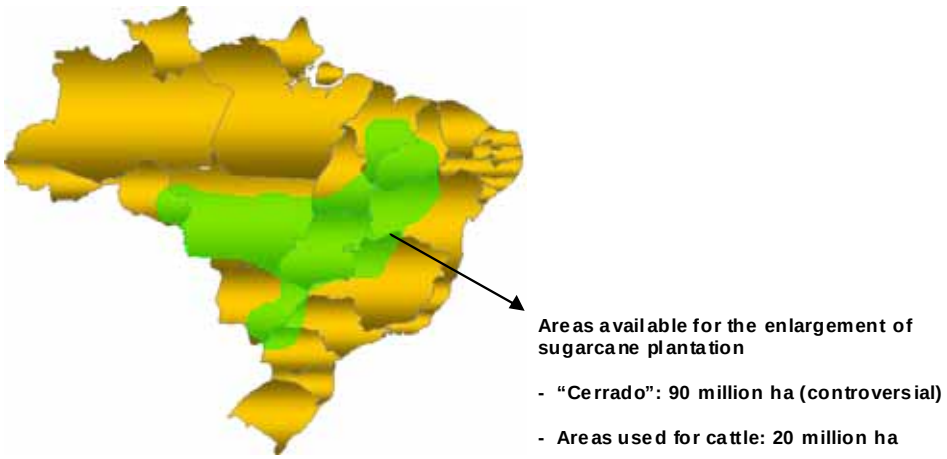
Sources: 2010 (Carvalho, 2005) and 2015 (Nastari, 2005a)

Considering these figures, the total sugarcane production should be 45% larger in 2010 and 80% larger in 2015 vis-à-vis the production during the harvest season 2004/2005. Considering an average yield of 77 t/ha/year, the total land requirement would be 7.2 million hectares in 2010 and 9.0 million hectares in 2015, i.e., 1.7 and 3.5 million hectares additional regarding 2005, respectively.

The use of land in Brazil for sugarcane production current corresponds to less than 2 per cent (about 5.5 million hectares) of the whole agricultural surface. In 2000, the land dedicated for soybeans production was about three times larger (16.5 million hectares), while the land occupied with corn plantations was almost twice times larger – 12 million hectares (Coelho, 2005). It is well accepted that large-scale sugarcane plantation in Brazil has not affected food production and even a substantial enlargement of the alcohol production would be possible without meaningful constraints. The harvested areas of corn and soybean crops have increased dramatically, while the area harvested for other cultures has remained almost identical for the past 35 years.

The total arable area in Brazil is estimated as 376 million hectares and, thus, it is considered that there is enough area available for the enlargement of the harvested area of sugarcane. However, the expansion of sugarcane in the “cerrado” area (the ecosystem in the Centre region of Brazil) should be carefully considered. Recently, sugarcane plantations have expanded mainly in areas previously used for cattle. Environmental legislation specifically

specifies that it is forbidden to engage in any type of deforestation. The area available for the enlargement of the agriculture, without deforestation, is estimated as 110 million hectares (see Figure 8). Thus, the required area would be about 2% of the land available.



Source: UNICA (2004)

Figure 8. Area available for the enlargement of the agriculture

The estimated additional production capacity of ethanol in 2013 would be 12.9 billion litres. Considering an industrial unit able to produce 80 million litres of ethanol per year, 160 new industrial units should be built up to 2013. The associated investment in the agriculture is estimated as US$ 2.3 billion, while the industrial investment is estimated as US$ 6.3 billion, summing up US$ 8.6 billion. According to equipment producers, Brazilian industry is able to build 24 blend new mills per year, i.e., 1.92 billion litres per year.

Despite the investment required, most of analysts consider that there is no deep constrain for the enlargement of ethanol production in Brazil in the short to medium term. In fact, production capacity is rising and new industrial sites have been built.

I.5 Sustainability aspects of ethanol production

Macedo (2002) states that the Brazilian ethanol production is an example for a sustainable large-scale program aiming at the production of energy from biomass. According to the author, the most important aspects from a sustainability viewpoint are yet accomplished or can be accomplished considering the available technology. The sustainability of ethanol

production has increased significantly and, in the São Paulo State, strict environmental legislation has been applied in any agricultural and industrial sector, including sugarcane production.

The following points illustrate the current status of this economic activity:

a) on average the output/input energy ratio (renewable/fossil) varies between 8.3 and 10.2, resulting in a substantial reduction on carbon dioxide emissions (Macedo *et al.*, 2004). All energy needs are met from the use of sugarcane bagasse (a by-product of sugarcane crushing) that explains why the energy balance is highly positive;

b) in 2003, in Brazil, the automotive use of ethanol represented avoided emissions estimated as 27.5 MtCO2 equivalent (Macedo *et al.*, 2004). Thus, alcohol from sugarcane is a significant option for countries to meet targets under the Kyoto Protocol;

c) by-products of the industrial production (vinasse and filter cake) usually replace fertilizers. This reduces the use of chemicals and avoids pollution of ground water and rivers, but so far the long-term effects of vinasse application on the soil are unknown;

d) in Brazil, sugarcane plantations are not irrigated, that implies low water consumption at the agricultural phase. On the other hand, water consumption is still very high at the industrial level and it's absolutely necessary to reduce it;

e) in the State of São Paulo, that produces 60-65% of the sugarcane, plantations must guarantee a preserved area (e.g., sugarcane is no longer planted in areas of watershed protection) and also must guarantee the local biodiversity. Considering the years to come, the expansion of agricultural frontiers based on deforestation or occupation of preserved areas is obviously an unacceptable solution (Nastari *et al.*, 2005);

f) harvesting with previous field burning is responsible for expressive emissions of NOx and particulate matter. In São Paulo State, existing legislation foresees a gradual growth on mechanized harvesting (that doesn't require field-burning), but full mechanization will be reached just by 2021-2031;

g) in Brazil it was possible to reduce lead additives by increasing the amount of ethanol in gasoline blend (lead was completely eliminated in 1991). Aromatic hydrocarbons (such as benzene) – which are particularly toxic –, were also eliminated and the sulphur content was reduced as well. In pure ethanol cars, sulphur emissions were completely eliminated;

h) sugarcane agro-business generates over 1 million direct jobs. In addition, wage levels in the sugarcane sector are comparatively higher than those in other rural sectors (UNICA, 2005);

i) ethanol production costs are low and fuel-ethanol is competitive vis-à-vis gasoline – with no subsidies – as far as oil barrel costs more than US$ 25 (Macedo, 2002);

j) in recent years, the genetic development of sugarcane species has advanced (e.g., more than 500 sugarcane varieties have been developed in Brazil). These developments have resulted reduction in the use of pesticides and of resultant environmental impacts, an increase of sugar content, the development of disease-resistant species, better adaptation to different soils, and the extension of the crushing season (UNICA, 2005) (Macedo and Nogueira, 2005);

k) due to the substitution of gasoline in the period 1976-2004 Brazil has saved US$ 60.74 billion (US$ December 2004) (valuing gasoline for its price in the international market). Considering interest on the avoided foreign debt, savings sum up US$ 121.26 billion (2.2 times the Brazil's foreign currency reserves and 24% of the total GDP in 2004). Also, during the period 1976 to 2004 fuel-ethanol has substituted a total of 1.44 billion barrels of gasoline that corresponds to 11% of Brazil's current proven oil reserves (Nastari, 2005b).

I.6 Conclusions

In conclusion, Brazilian experience on bio-ethanol production is remarkable. The moment for the enlargement of its production is very favourable, both considering the domestic and the international market. Regarding the domestic market, the advent of flex-fuel vehicles is a milestone and uncertainties concerned to long term perspectives for neat ethanol vehicles should be overcome. Regarding the foreign market, there are good reasons for predicting it will enlarge, especially due to the rising concerns about climate change. However, despite

high competitiveness of Brazilian industry, its participation in the international trade will also depend on the elimination of trade barriers.

On the other hand, fuel-ethanol use is only justifiable if its production is effectively sustainable. In this sense, sustainability criteria should be clearly defined to assure sustainability in itself and not to impose additional barriers for trading. Nowadays, Brazilian ethanol production is much more sustainable than it was in the past and it is probably more sustainable than in other countries. However, to make a reality its potential participation on fuel-ethanol trade it will be necessary to become a benchmark on bio-energy production from a sustainability point of view.

Finally, it is important to take in mind that a considerable number of developing and transition economy countries – which have in agriculture a large share of their wealth – see "energy farming" as a way to improve life conditions and the economy in a sustainable way. Therefore the support from industrialized countries to bio-fuels production and its wide use is not just a way to reduce dependence on fossil fuels, but is also a clever and cost-effective way to induce progress in less developed parts of the globe. Fuel-ethanol produced in a developing country and used in the developed world is effectively a win-win situation that offers the opportunity of environmental and energy benefits to one side while creates a new source of income and well-being to the other side.

Part II – Wood Production

II.1 Introduction

Wood production is a well-established activity in Brazil. Giving an idea about its importance, it has been noticed that by now the forest sector offers about 700 thousand direct jobs and two million indirect jobs[12] (Couto and Dubé, 2001).

According to Couto *et al.* (2002) Brazil has the best technology for implementation of dedicated forests of eucalyptus in the world. Average yields in the range 20-25 m³/ha/year are usual due to the short cycle of these plantations – 5 to 8 years, for industrial purposes. Owing to the high productivity prices for eucalyptus before harvesting are currently estimated between as just 0.5 and 0.6 US$/GJ[13,14] (ABRACAVE, 2003).

Plantations of eucalyptus have been condemned for some years. Couto *et al.* (2002) have analysed environmental aspects of this practice and concluded that some of the constraints of the past are no longer a matter of concern. In particular, the authors assert that problems such as soil drainage, soil degradation, nutrient leaching and reduction of water storage capacity can be almost completely avoided if adequate techniques are applied. For instance, comparisons of eucalyptus species with other forest plants demonstrate that eucalyptus plantations in Brazil consume the same quantity of water as native forests. Regarding biodiversity preservation, the usual solution is both to form and maintain wildlife corridors connecting areas under conservation (native vegetation).

Brazil has about 5 Mha of sustainable forests (afforestation and reforestation), with 56% of these forests located in the South East region. Eucalyptus represents 64 % and pines 36 % of this area (BRDE, 2003). Most of wood from pinus is harvested in the South region, and its main destination is for timber industry. From the overall amount of planted forests consumed

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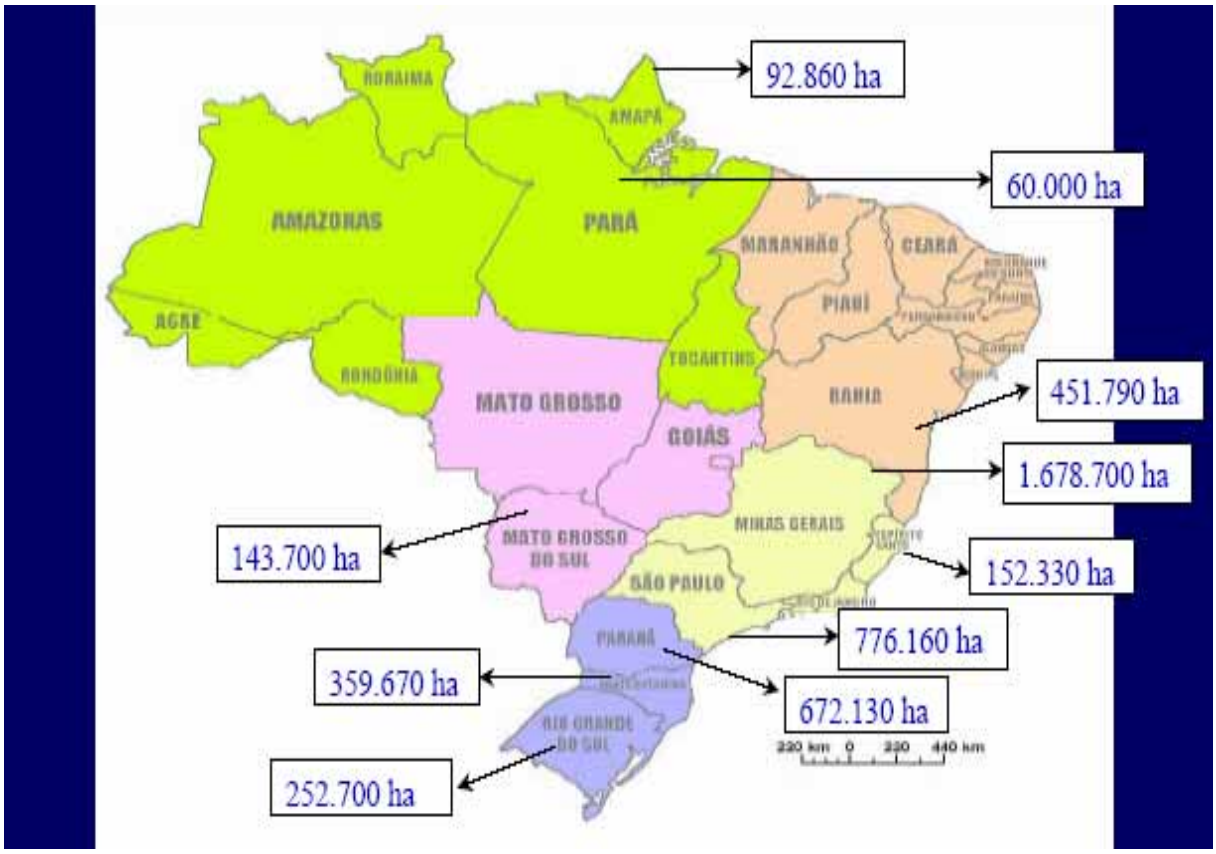
[12] Just the partnership program for eucalyptus cultivation of Aracruz Celulose with small farmers (the Aracruz Forestry Partners Program), has contributed with US$35 million in the form of taxes and wood purchases, and has generated some 5,000 jobs (Aracruz, 2002).

[13] 1 US$ = 3 R$. An estimate is that harvesting, bark removal, cutting and transfer to an open area add 0.35-0.50 US$/GJ.

annually, 33 % is for charcoal production, 13% for wood with industrial energy purpose, 31% for pulp and paper mills, and 23% for timber industry (BRDE, 2003).



Source: SBS (2002)

Figure 9. Forest plantations in 2002

II.2 Four decades of plantations – an overview

In 1965, the existence of just 0.5 M ha of plantations and a growing pace in deforestation led to a revision in the ongoing forestry legislation updating the Forestry Code. In 1967, the IBDF- Brazilian Institute for Forestry Development was created, together with a national program to foster forestation, named Brazilian Tax Incentive Law. It ruled during 20 years and the approved projects should have covered an area of about 6.5 M ha, which in practice were not verified.

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[14] In early 1990s a study regarding large-scale electricity production in Northeast Brazil has estimated that 50 million hectares could be used for eucalyptus plantation, producing biomass at an average cost of 1.36 US$/GJ (Carpentieri *et al*. 1993). It could be noticed that the quality of soil in Northeast Brazil is, general sense, poor.

In the 1990's there was a reduction in the forested area from more than 300 thousand ha/year to about 170 thousand ha/year. Reasons: the end of the program above, unstable economy, lack of financial resources and high interest rates. Pulp and Steel industries, during the 1990's, were responsible by most of those plantings. These industries, having enough financial resource and stable external market, were stimulated by the new local technologies, which provided increasing wood yields.
In 2000-2003 forested areas held about 250 thousand ha/year, an amount still lower than the harvested area. Pulp and Steel industries have not facing problems with wood supply such as timber industry has (they have mature forests planted in the 1990's). Some timber consumers are importing wood from MERCOSUL.

During recent years, environmental and social concerns started to be demanded in the forestry sector. Bio-energy from wood has its demand and supply estimated as about 70 M t for 2003. About 10% from that amount is regarded to be from sources of unknown sustainability (Nogueira and Trossero, 2004).

Field residues have been rarely used for energy production, remaining as an important alternative for both internal and external bio-energy trade. Saw mill residues have been used more frequently than field residues (wood slashes), although their uses are still low and mostly inefficient.

II.3 National programs

Several programs are being implemented to supply demands generated by the forestry sector such as Pronaf Florestal (Forestry Program for Familiar Agriculture Support), Propflora, Profloresta, and Proambiente. They have acted increasing annual planted forests through funding it at low rates, and incorporating native sustainable forests through certification process (e.g.: FSC – Forest Stewardship Council).

Targets for planted forests from 2004 to the end of 2007 (4 years) are to plant 0.8 M ha through small and medium farmers; 1.2 M ha through medium and large companies; 75 thousand ha to recover riparian forests and 125 thousand ha to rebuild legal farmland reserves

(80% Amazon, 35% Amazonian cerrado and 20% for the rest). For native forests in this period of four years, it is expected that 15 M ha of native forests will be certified and sustainably managed, in which 5 M ha must come from "Social Forests" managed in a community or familiar way.

Electricity generated on site from wood biomass (mainly residues) by 2007, according to government projections is expected to be about 1.5 GW.

It is also estimated that the contribution as a result of these package of programs, a contribution for reducing GHG emissions would correspond to 50 M tCO_2 equivalent (avoided emissions and storage).

II.4 Flows at present - current wood energy uses

II.4.1 Charcoal

Brazil produced 7.3 M t charcoal in 2003 (ABRACAVE, 2003), equivalent to 225 PJ. Steel industry consumes 85% of this amount, in which charcoal plays at the same time the role of reducing agent and source of energy. Households come in the second position with a rate of 9%, using it for cooking and heating. Bakeries, restaurants, and other small business activities come right after with 1.5% (Cenbio, 2004).

Charcoal exports are very small in comparison to the production[15], and it has been in the last years almost equal to the amount imported. In 2003, 0.4 PJ was exported for small purposes, notably the domestic and commercial ones, packed and certificated as environmentally friendly. There is an entity named ABPED – Brazilian Eucalyptus Producers Association for Residential Use, which trades charcoal with a label called Sofex. Average price for this charcoal exportation in 2003 was U$ 191/ton (FOB), getting an added value of about 60% on general domestic prices in the same year which were 84 U$/t (2.7 U$/GJ) (ABRACAVE, 2003). On the other hand, importation has occurred mainly in south of Brazil, from neighbourhood countries, like Paraguay, at general prices.

Its production has sharply increased during the 1980s in response to a government policy aiming at reduce imports of coal and coke. The peak of charcoal output was in 1989, when

almost 40 per cent of the pig-iron production was based on this biomass source (it was just 27 per cent in 2000). During the 1990s large-scale integrated steel mills shifted again their energy matrix, returning to coke due to its reducing costs. Currently, just one large steel company is committed to using 100 per cent charcoal, while charcoal use in pig-iron production is concentrated in small independent factories[16].

From the point of view of sustainable bio-energy trade chain, past Brazilian large-scale charcoal production has not accomplished some important criteria. Rosillo-Calle and Bezzon, (2000) mention the following drawbacks of the charcoal program during the 1980s:

i) Most of charcoal production during the 1980s was based on native forests – more than 80 per cent in some years – located very close to the steel mills. Rapid deforestation motivated a new regulation for forests preservation. As result, in 1997 about 87 per cent of the production of charcoal consumed by steel mills was based on dedicated plantations, while this share reached 97 per cent in 1999. Regarding the overall production of charcoal, currently about 73.9 per cent is based on planted forests (ABRACAVE, 2003).

ii) Abusive labour practices were usual in 1980s and an expressive share of charcoal production at that time was based on children work force.

iii) Modernization of most backward sectors and increase in efficiency to reduce costs were required at that time, making uncertain the long-term future of the charcoal-based industry.

Charcoal can gradually recover its feasibility vis-à-vis imported coke due to the phasing out of charcoal production from native forests[17] and to the improvements in the conversion process[18]. Nevertheless, further technological improvements are still required to assure the survival of this activity, such as increasing conversion yields, developing cleaner carbonization techniques and, more important, making better use of by-products such as

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[15] 12.8 thousand tons, or 1.78 per cent of the charcoal production in 2003 (2.5 million US$ FOB). The maximum exportation was in 1994 – 18.4 thousand tons with revenue of 2.8 million US$ (FOB) (ABRACAVE, 2003).

[16] About 65 per cent of the charcoal consumption in this industrial sector is due to independent producers of pig-iron.

[17] Reducing transportation costs and reaching economies of scale on charcoal production. The price of charcoal produced from dedicated forests is nowadays equal to the price of charcoal produced from native forests.

[18] Improving the conversion efficiency to about 36 per cent, as described above.

liquid fuels and chemicals through gases and liquids recovery (Rosillo-Calle *et al.*, 1996 and Rosillo-Calle and Bezzon, 2000).

Recent research on charcoal ovens has developed a technology which improves efficiency of pyrolysis from the average 330 kg of charcoal currently obtained per ton of wood, to 450 kg per t of wood. It is called DPC – Drying Pyrolisys Cooling (UFMG, 2004).

II.4.2 Firewood

Brazil produces as primary energy source from forests, about 55 M t of firewood. From this amount, further than 40 % is for charcoal, they are 33 M t representing almost 580 PJ, from which 29 % is for residential use, mainly for cooking, and 23 % is for industrial and commercial uses such as steam generation, drying and heating process for brick, beverage, crop and food production (Cenbio, 2004).

II.4.3 Wood chips

Wood chips may be done with forest residues as well as with logs or trunks (whole trees). They have been used for many applications like paper a pulp industry, brick and ceramic industry, energy and other uses. Most of chips exported are made of logs, meeting strict patterns set by their users. They are employed in the paper and pulp industry, and their main destination is Asia. An exporter company has started a chip production to supply electric and heating plants in Europe, using acacia trees and barks of eucalyptus and pinus. Numbers in 2004 will hold 250 thousands GMTs (green metric ton) which correspond to 3 PJ (Omachi et al., 2004). Prices change according to the moisture, which may reach 40 % for GMT. Values are about 25 U$ /GMT Fob.

II.4.4 Wood pellets

Wood pellets are made almost exclusively of forests and sawmills residues, which are the cheapest and the most abundant source of biomass available in this country. Prices from it are ranging from 0.7 (free on board in the Amazon) to 1.7 U$/GJ (transported in the Southeast). It is estimated that from the overall declared Brazilian annual wood consumption (180 M t) (SBS, 2003), a rate of 15-20% is regarded to residues. It means that more than about 50 M m3 or 30 M t are barely used at present (Cenbio, 2004). However, production of wood pellets does not have significant expression yet. Small producers have been providing it for some restaurants, bakeries, domestic grills, looking at substituting charcoal and firewood. Just in the

metropolitan region of São Paulo, about 1.8 M t of firewood equivalent have been consumed annually. There are approximately 5.000 pizza-houses and 8.000 bakeries, in which ones 70% of energy source is charcoal and firewood which is being gradually changed to wood pellets. They are cleaner, denser both in mass (1.2-1.3 t/m3) and energy (20.5 MJ/kg) than firewood, which means transport saving; they may provide better uniformity in the process of burning and therefore, efficiency (Cenbio, 2004). There is a company in the Southeast, which will be exporting 10,000 t of wood pellets and briquettes to North America up to the end of 2004. Briquettes are packed, and their main destinations are domestic use, restaurants, and bakeries. For 2005 numbers may reach 25.000 t. Its cheapest prices for packed pellets are presently at 52 U$/t (2.7 U$/GJ) (Couto *et al.*, 2004).

II.5 Sustainability on wood production – an overview

II.5.1 Technical and environmental aspects

i) Average annual yield: 25-50 t/ha for eucalyptus (7 years) and 20-40 t/ha for pines (12 years);

ii) Up to 3 harvests per planting for eucalyptus;

iii) Charcoal - increasing efficiency leading from 330 to 450 kg / t of wood (+ 36%), together with the achievement of 100 % from planted forests for 2010;

iv) No-tillage or reduced tillage is the usual method of planting;

v) Highly reduced input of chemicals;

vi) At licensing stage, it is required the adoption of general BMPs (e.g.: wildlife corridors, riparian vegetation, nutrient cycling and others). The Code of Best Practices for Planted Forests is still under construction;

vii) Land availability for new forests may be met inside the 10 M ha already forested, even considering rotation practices. Reasons: short-term rotation and increasing earnings obtained in productivity;

viii) Additionally, small farmers are foresting marginal lands, not appropriated for other purposes;

ix) There are 400 M ha of Native Forests for a estimated management of less than 7% for National Program and other initiatives.

II.5.2 Legal aspects

i) After Constitution of 1988 the Environment National Policy and the SISNAMA – Environment National System started, in fact, to be implemented. Environment Agencies at State level became responsible to issue licenses for activities both at running or initial phase;

ii) Some States have their EA still under structuring. In that places activities remain controlled by national agency which unfortunately does not have enough structure to do it;

iii) EIA is required for all medium and large projects, even in Amazon where National Agency cares for it. This is another reason why many small projects remain deforesting and polluting;

iv) Legal framework established in 1998/99 set sanctions for environmental crimes enabling enforcement efficacy;

II.5.3 Social aspects

i) Forestry sector is responsible for 0.5 million direct jobs and 2.5 indirect ones. It is expected an increase of 10% up 2007, as a consequence of the National Programs and of the stable economy;

ii) The most important companies are now working under the "integrated system", which consists of a partnership between industry and landowners, mainly small farmers. In this system industry provides clones (seedlings) and all other agricultural materials; farmers participate with land and work-force;

iii) A target from National Programs states, for this decade, that about 250 thousand rural families will be maintained by 5 M ha of "Social Native Forests" certified and sustainably managed (Brazil has about 50 M ha of National Forest Reserves);

iv) Attractive financial resources linked to National Programs are loaned by public banks. They require from any operation, the strict legal accordance to all labour aspects;

v) A charcoal producers association together with the State of Minas Gerais Government are implementing a certification process (Forestry Origin Stamp) for internal and external markets (named SOFEX and SOFIN). This certificate (stamp) assures that this charcoal was produced according to Brazilian labour and environmental laws.

II.6 Supply – trends and perspectives

Brazilian forestry sector has harvested more hectares than it has planted. In addition, expansion of timber, paper and steel industries have been increasing demand. As a result of this, there is an importation of softwood (pines) in the South region estimated in 14 M m3 for 2004, which increasing in about 2 Mm3 each year. In 2006 it will begin also for hardwood (eucalyptus), with 3 M t of importation, growing 100 % each year (SBS, 2003).

However, considering the existence of approximately 50 Mm3 of forest residue practically forgotten, it should be considered the utilization of this as an energy source in place of eucalyptus, which may supply part of pulp and paper industry. Consequently, paper and pulp industry may release part of its pines forests to be used by timber industry, which one is the biggest importer of wood today. In a such way its already happen today in the South, where paper industry is exchanging its big logs, harvested from mature forests, for small and thin logs removed from the field to reduce plants population, and to permitting better growing of the remaining ones. In conclusion, numbers may imply that adopting this procedure in larger scale, internal demands will be achieved and probably, some surplus for external market. In a horizon of 7 to 10 years, when new plantations and reforestation as mention before were ready to be harvested, as a result mainly from the National Programs, Brazil will have great availability of forest biomass to be exported.

In addition, results presented in Table 4 below confirm the statement above and show how wood residues may help to shift internal pattern of uses of noble logs, and also how it may contribute to generate surplus able to be exported. Residues such as considered in this work have addressed the issue nutrient cycling as well as they have supposed to come wholly from planted and native certified forests, observing therefore sustainability criteria.

Table 4. Forestry Sector in Brazil - Present figures and perspectives

Indicators	Unit	2002	2005	2010	2015	2020
Planted Area	k ha/yr	200	500	500	500	500
Harvested Area	k ha/yr	(378)	(480)	(592)	(673)	(765)
Stock Changes(a)	k ha/yr	(178)	20	(92)	(173)	(265)
Supply	M t /yr	44	55	80	150	150
Demand	M t /yr	(70)	(85)	(125)	(150)	(175)
Surplus (b)	M t /yr	(26)	(30)	(45)	0	(25)
Residues (c)	M t /yr	75	95	115	135	156
Biomass surplus (d)	M t /yr	49	65	70	135	131
Bio-energy surplus (e)	E J /yr	0,41	0,55	0,59	1,13	1,10

Notes:

a) Although growing stock changes in 2005 appear to be positive, they reflects only the industrial situation, which have been planting regularly. Small timber consumers are facing problems to get mature pine wood logs. In addition, there is need for increasing plantings after 2005 in order to meet increasing demand.

(b) Negative surplus are due to low amount of plantings undertaken in the 1990s. Increasing in forested area observed after 2004, will just start to show results after 7 years for eucalypt and 12 years for pinewood.

(c) Industrial (sawmill) and field residues from planted forests.

(d) Net biomass amount considering negative and positive surplus (- /+).

(e) Net bio-energy amount considering negative and positive surplus (- /+).

II.7 Wood bio-energy trade: barriers, incentives and key issues for facilitating future development

II.7.1 Logistics

A considerable amount of planted forests is presently located at places were freight is quite expensive up to maritime ports, mainly because of the high cost of transporting biomass by trucks. Values may increase about 150% on the biomass fob price in some places, three times the maritime value from the Brazilian coast to Europe. Fluvial transport may be a solution for the Northern and Western-Western region due the existence of several rivers (Madeira, Tapajós, Amazonas, Xingu, and Araguaia) appropriated for this purpose. For the North-eastern and South-eastern regions (Parnaíba, São Francisco, Doce, Tietê) fluvial transport should be mixed with railway as the main alternatives. For all those regions, crops transport has already started through a multi-modal way in which one connections are made by trucks. Mass densification through pellet and briquettes production may be an alternative to reduce costs of transport for some cases but it depends on an appropriate cost-benefit analysis. Recent studies made by Dolzan and Walter (2006) have pointed that among 17 places of production considered (figure 10 below), if no improvement in logistics is assumed, just one (Amapá) have presented competitive prices for exporting pellets to Europe (Netherlands). However, considering a series of new configurations and improvements in logistics, the number of places with competitive pellet prices for exporting would rise to 14.

Figure 10 – Places for existing biomass production (red points) and for future biomass production (yellow points); and their nearest ports in 2005 (adapted by Dolzan & Walter, 2006, from Ministry of Transports, 2005)

II.7.2 Interest rates

Financial costs in Brazil are regarded to be among the highest ones in the world. Long term business become sometimes unattractive under discount rates of 20-30% / yr. The Brazilian Developing Bank – BNDES, as well as other public regional banks, have resources at lower interest rates. Small forest farms are eligible to get loans under rates below 10% / yr. Big projects whether in accordance with environmental, social and legal criteria set by those banks, are also eligible to more affordable rates ranging from 12 to 18 % /yr. Financial contracts made in external money may also help to reduce this problem, however they are not easier to be obtained for small and medium companies. Another point to be set is land prices

in Brazil which are reasonably low, helping to reduce overall production costs, and therefore to mitigate higher financial costs.

II.7.3 Taxes

On average, products receive 40% of taxes and also. Furthermore, net income pays taxes ranging from 10 to 27.5 %. There are rare incentives in this issue beyond those traditional alternatives obtained through financial and accounting engineering.

II.7.4 Ports

Brazil is highly privileged in terms of places for structuring ports such as it can be seen in the figure 10 above. However, most of the existing ports are public and their services are both expensive (outstanding tariffs) and inefficient (there are some exceptions). In addition they are not equipped for fast carrying of wood pellets or chips which both have low aggregated value. To solve this problem, private ports located at strategic places and conveniently equipped with belt-carriers have been used for wood chips exports. A least three big companies for both energy and pulp purposes have their own ports (Amcel – AM, Aracruz - ES and Tanac - RS). These companies have presented highly competitive prices at outstanding levels if ordinary freights and port taxes are taken into account and the likely reason is efficiency not dumping (Dolzan & Walter, 2006). Also, higher aggregated value products such as high density briquettes and packed charcoal for residential uses, may confront higher prices as well as their volumes are lower and generally are shipped into containers.

II.7.5 General aspects

Lack of constancy e continuity on international wood bio-energy exports does not permit to get both maturity and scale earnings, as well as it repels investments. These needs together with lack of long-term contracts make difficult to reach a market of stable prices. Currency fluctuations are less common at present. However, the current valuation of the Brazilian Real becomes other alternative domestic uses more attractive than exports. Credit opportunities for exporters loaned in external money may improve attraction for exports. Another likely alternative for these barriers could be in developing a strong domestic market, diversified in number and type of suppliers and consumers, in the same pace as production grows (excepting charcoal). Then, scale and maturity would be brought to the wood bio-energy

scenario and consequently more stable prices, as it happened with alcohol, after the gasoline blend, and recently through the flex fuel cars.

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