



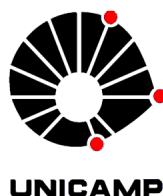
IEA Bioenergy

Country Report

Brazil

IEA Bioenergy Task 40

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Brazil

Country Report 2009

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Abstract

Worldwide, few countries as Brazil have an energy matrix with such an important share of renewable energy sources: in 2007, almost 46% of its primary energy supply was covered by renewables, being the share of biomass sources estimated as 29.3% of the total energy consumption (2,350 PJ). The most remarkable biomass experience is due to fuel ethanol production/consumption at large-scale, reaching the production 27.6 billion litres in 2008 (19.6 BL consumed in Brazil and 5.1 BL exported). More recently, Brazil started a biodiesel program (by the end of 2004) and since July 2009 B4 blends (4% of biodiesel in fuel blends, volume basis) are mandatory countrywide; in 2008, biodiesel consumption was close to 1.2 BL. Regarding ethanol, Brazil is an important player in the international trade scenario, with perspectives of enlarging its share in the years to come. On the other hand, regarding biodiesel, Brazil can consolidate in short-term a position as one of the top world producers, but barely will be in an exporter. There are also constraints regarding solid biofuels (such pellets), and the existing potential will be barely be developed in short-term. The lack of adequate logistics is currently the main barrier for trading biomass at large scale, even in case of ethanol. Sustainability of biofuels/biomass production is the challenge to be faced in the years to come, despite the fact that a significant share of ethanol production in Brazil – also regarding forest products – could be already considered sustainable.

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Introduction

This is the second edition of Brazil's Country Report, prepared in the context of the IEA Bioenergy Task 40 Sustainable Bio-energy Trade; securing Supply and Demand. The first edition of this report was delivered in 2005.

Since that year, Brazil experienced the first four years of its biodiesel program, with the mandatory biodiesel consumption reached 4% of the mineral diesel in July 2009. In 2008, when B2 blends were mandatory during the first half of the year, and B3 otherwise, the consumption was close to 1.2 billion litres. On the other hand, ethanol domestic consumption has raised continuously since the launch of flex-fuel vehicles in March 2003, and was close to 20 billion litres in 2008.

Regarding solid biomass, the consumption of firewood and charcoal has been almost constant in recent years. The consumption of pellets is still irrelevant, while there is optimism concerning the growing availability of sugarcane residues (bagasse and trash).

There is also optimism regarding electricity production from biomass, mainly from sugarcane residues, that has slightly grown since the 1990s. However, there are still barriers that make impossible taking full advantage of the existing potential.

This reports is organized in eight chapters. Chapter 1 presents general information about Brazil (geography, demography and economy), its energy matrix and data available about greenhouse gas emissions. Energy policies regarding biofuels/biomass production and consumption are presented in Chapter 2.

Chapter 3 presents the biomass resources in Brazil, while Chapter 4 presents current figures and expected future energy use of biomass.

Chapter 5 is devoted to the biomass prices and Chapter 7 to the analysis of barriers and opportunities for biomass (and biofuels) exporting. Finally, Chapter 8 presents the final remarks by the authors of this report.

Complementary information is presented in an Annex.

1. General Information

1.1 Geography, Demography and Economy

Brazil is worldwide the fifth largest country by geographical area, and the fifth most populous country; is the largest country where Portuguese is spoken. Is located in South America and occupies almost 50% of that region; Brazil has boarders with all South American countries, except Chile and Ecuador.

Figure 1.1 presents its position in South America and details of its topography. It is important to notice that by 2005, according to UNDP (2009), 57.5% of the country area was still covered by forests (4,770 km², the second largest area in the world, after Russian Federation).



Source: Wikipedia (2009)

Figure 1.1. Brazil in South America and its topography

According to the last official demographic survey, in 2007 the Brazilian population was almost 184 million inhabitants (IBGE, 2008)². The average population growth between 2004 and 2008 is estimated as 1.1% per year. Brazil is divided in five geographic regions, and the population in each one is presented in Table 1.1. The five geographic regions are presented in Figure 1.2.

² Considering the historic growth rates, Brazilian population by mid-2009 is estimated as 191.4 million people (IBGE, 2009).

Table 1.1. Demographic information – Brazil, 2007

Region	Population (1,000)	Area (1,000 km ²)	Density (hab/km ²)
North	14,623.3	3,851.6	3.8
Northeast	51,534.4	1,556.0	33.1
Southeast	77,873.1	927.3	84.0
South	26,733.6	575.3	46.5
Centre-West	13,222.9	1,604.9	8.2
Total	183,987.3	8,514.9	21.6

Source: IBGE (2008)



Notes: Region 1 – Centre-West, with three states and the Federal District (Brasília); Region 2 – Northeast, with nine states; Region 3 – North, with seven states (is where most of the Amazon region is located); Region 4 – Southeast, with four states; Region 5 – South, with five states.

Figure 1.2. The five geographic regions in Brazil

In Latin America Brazil has the largest market and is the world tenth economy in GDP terms, based on market exchange rate (and the eighth largest economy as long as GDP is expressed in purchasing power parity – PPP) (The Economist, 2009).

The GDP in 2008 (market exchange rate basis) was 1,575.2 trillion US\$, with a growth of 5.1% regarding 2007 (on average, the annual growth rate was 3.5% from 2004 to 2008). However, it is estimated that in 2009 the GDP will contract by 1.2% (The Economist, 2009). The GDP per head in 2008 was estimated as 8,209 US\$ (10,325 US\$, considering PPP basis).

A big issue in Brazil is income inequality (Gini Index 0.57 in 2007-2004³) that has slowly declined due to income support programs. The Human Development Index in 2005 was estimated as 0.80

³ To be compared with the Gini Index in Denmark, Japan and Sweden (24.7, 24.9 and 25.0, respectively) (the best figures worldwide) and with Sierra Leone, Lesotho and Namibia (62.9, 63.2 and 74.3, respectively, the worst figures) (UNDP, 2009).

(70th place in the world rank), with a continuous trend of improvement since 1975 (e.g., 0.649 in 1975, 0.70 in 1985 and 0.753 in 1995) (UNDP, 2009).

By 2008, more than 55% of the total GDP was due to the Services Sector, being the contribution of industries estimated as about 24%, and of agriculture less than 6%; the complement corresponds to taxes over products (about 16%). In 2008, total exports represented about 14% of the GDP, while total imports were slightly lower (IBGE, 2009).

The main industrial branches in Brazil are: automobile, petrochemicals, machinery, electronics, cement, textiles, food and beverages, mining, aircraft, etc. The main products of Brazil's agriculture are soybeans, coffee, beef, citrus, sugarcane, rice, corn, cocoa, etc. Table 1.2 presents the main figures regarding foreign trade in 2008.

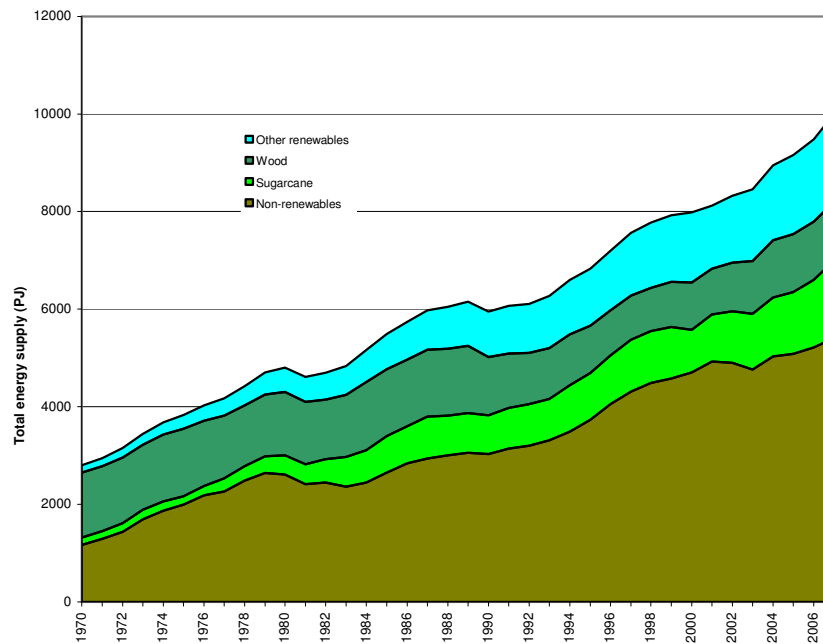
Table 1.2. Foreign trade figures (% of total for the leading markets and leading suppliers)

Major exports	Major imports	Leading markets	Leading suppliers
Transport equipment & parts	Machinery & electrical equipment	US – 15.6	US – 15.5
Metallurgical products	Chemical products	Argentina – 9.0	China – 10.5
Soybeans (meal & oils)	Oil & derivatives	China – 6.7	Argentina – 8.6
Chemical products	Transport equipment & parts	Germany – 4.5	Netherlands – 0.9

Source: The Economist (2009)

1.2 Energy

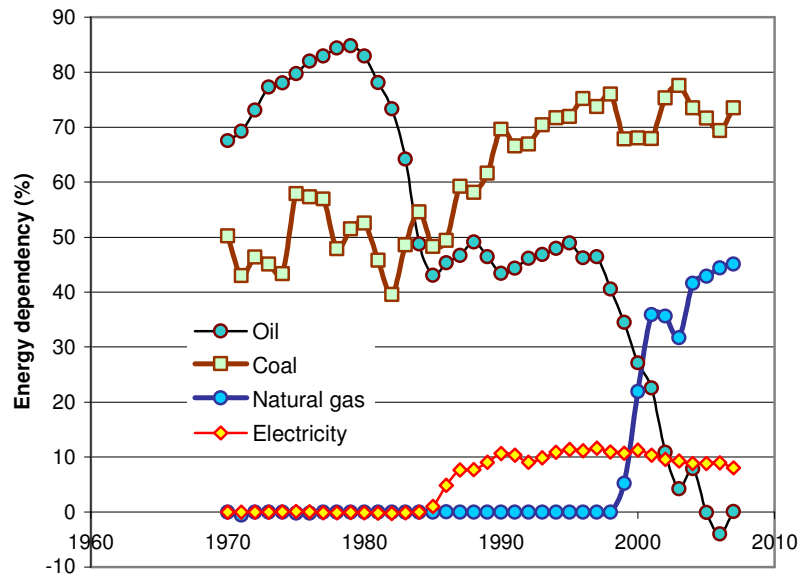
Few countries with reasonable to good level of industrialization, like Brazil, have an energy matrix with such an important share of renewable energy sources. In 2007, almost 46% of its primary energy supply was covered by renewables. The share of hydraulic energy that year was 14.9% of the total supply. In the same year, the set of biomass sources covered 27.8% of the domestic energy supply, with a share of 15.9% of sugarcane products (ethanol and bagasse). Figure 1.3 shows the evolution of the total energy supply in Brazil in the 1970-2007 period, and highlights the share of renewables.



Source: EPE/MME (2008)

Figure 1.3. Evolution of total energy supply in Brazil – 1970-2007

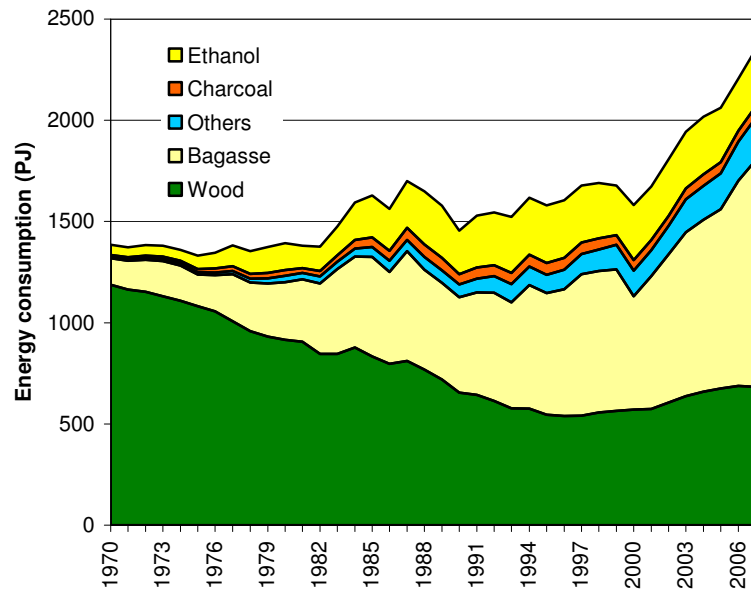
Along the last three decades or so, Brazil has remarkably reduced its dependency on oil supply and is currently (on average) self-sufficient. On contrary, Brazil is highly dependent on high-quality coal (and coal coke), used on iron and steel production; this dependency was reduced in the early 1980s, when Brazilian government implemented policies aiming at substituting coal coke for charcoal, but imports raised again when coal's (coke's) prices declined. The dependency on natural gas is a new event, and started with the imports from Bolivia; Brazilian government (and PETROBRAS, the stated-controlled oil company) has worked on enlarging domestic production and diversifying suppliers. Finally, the dependency on electricity is mostly due to the imports from Paraguay, as this country is owner of 50% of Itaipu's capacity (a largest hydro power plant, with almost 14 GW installed). Figure 1.4 shows the evolution of external dependency on oil, coal, natural gas and electricity.



Source: EPE/MME (2008)

Figure 1.4. Evolution of total energy supply in Brazil – 1970-2007

Details about the contribution of biomass over the final energy consumption in Brazil are presented in Figure 1.5. It can be seen a continuous reduction of wood consumption until mid-1990s that was strongly influenced by the reduction of non-commercial wood consumption by households. It should be noticed that the data regarding wood consumption, mainly in households, are based on estimations. Bagasse consumption corresponds to the use of sugarcane bagasse as fuel in mills that produce ethanol and sugar; there, bagasse is used with low efficiency as fuel in boilers, and this is the reason of its high share. In Figure 1.5, "Others" correspond to different agricultural and industrial residues, such as black liquor.

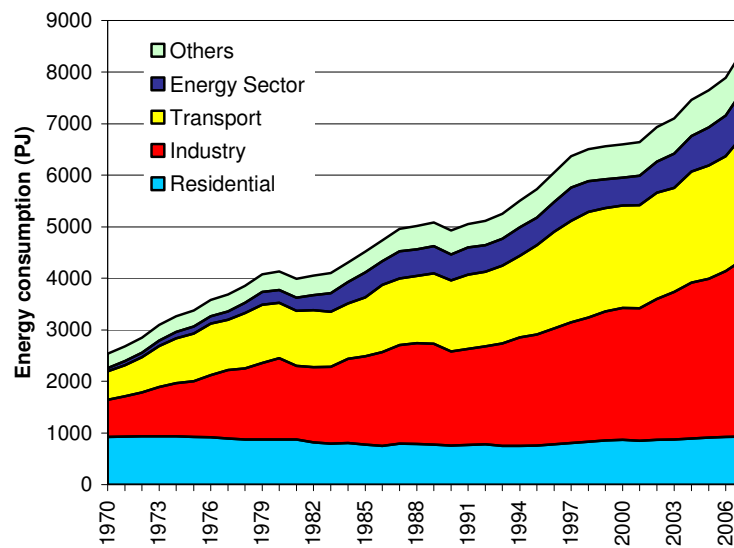


Source: EPE/MME (2008)

Figure 1.5. Final energy consumption of biomass sources – 1970-2007

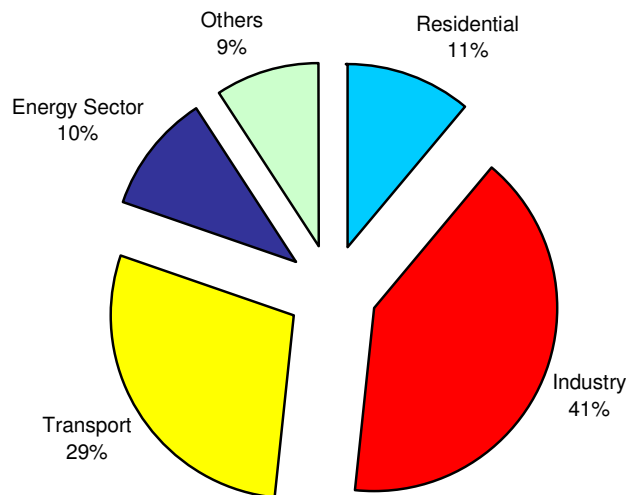
The bulk of wood consumption is in the residential (48%) and in the industrial sectors (37%). The energy consumption of charcoal is mostly due to the industrial sector (90%), and more specifically in the metallurgic industry.

Considering socio-economic sectors, the industrial is the one with highest consumption (3.4 EJ by 2007; 41% of the total), followed by the transport sector (2.4 EJ and 29% of the total by 2007). In Brazil, the energy consumption in the residential, commercial and in the energy sectors reflect some specific aspects: first, due to the weather conditions, space heating is not required in most of the regions; second, due to the importance of hydroelectricity, the total consumption in the energy sector is not too high. Figure 1.6 shows the growth of final energy consumption by sectors from 1970 to 2007. Figure 1.7 shows the distribution of final energy consumption within socio-economic sectors by 2007.



Source: EPE/MME (2008)

Figure 1.6. Energy consumption by sectors – 1970-2007

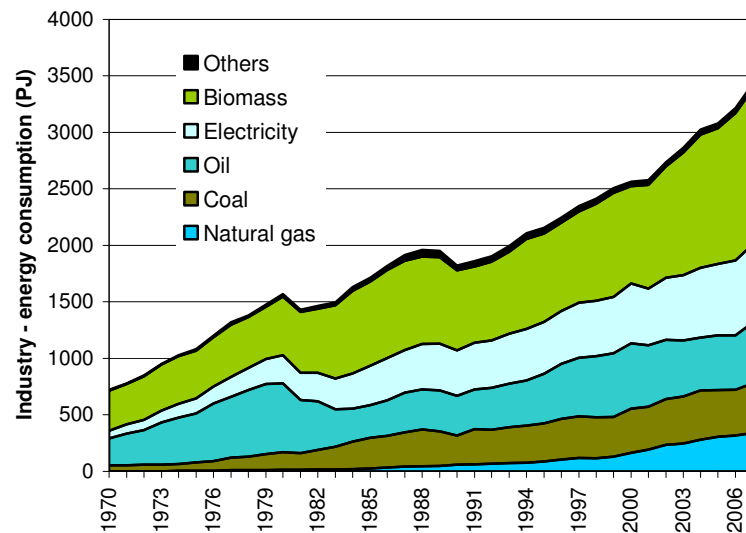


Source: EPE/MME (2008)

Figure 1.7. Energy consumption by sectors in 2007

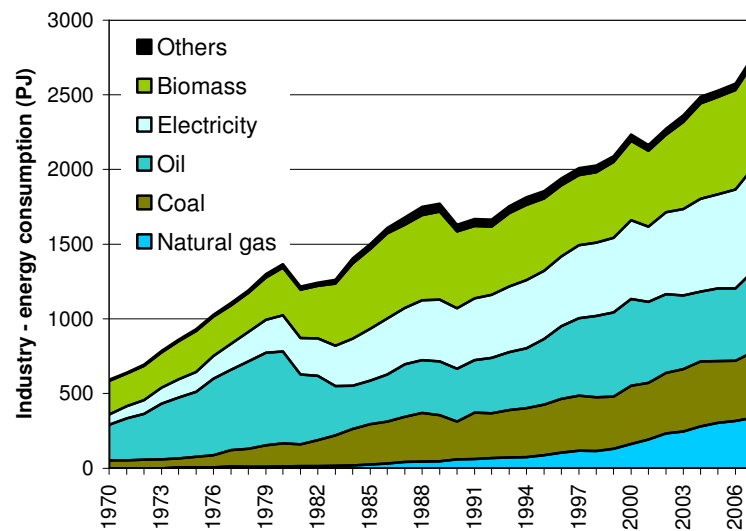
The evolution of the final energy consumption within the industrial sector is shown in Figure 1.8 and Figure 1.9. The difference between these two figures is the inclusion (or not) the of the sugar industry in the industrial sector. Most of the sugarcane mills in Brazil produce both sugar and ethanol, but from the point of view of energy statistics, the consumption for sugar production is

classified as industrial sector, while the consumption for ethanol production is allocated in the energy sector. The difference is almost 680 PJ in 2007.



Source: EPE/MME (2008)

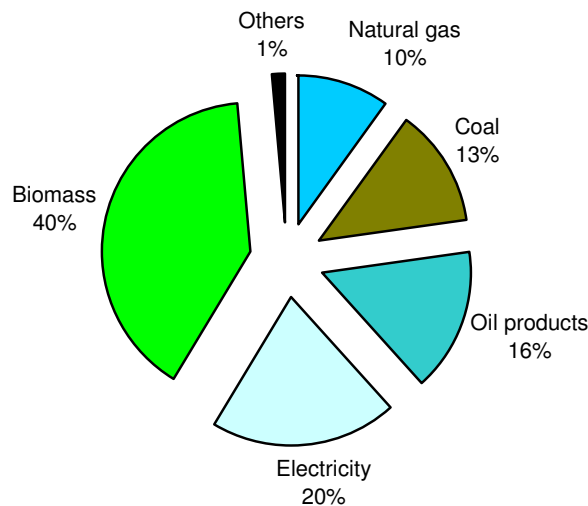
Figure 1.8. Energy consumption in the industrial sector, including bagasse consumed for sugar production



Source: EPE/MME (2008)

Figure 1.9. Energy consumption in the industrial sector, excluding bagasse consumed for sugar production

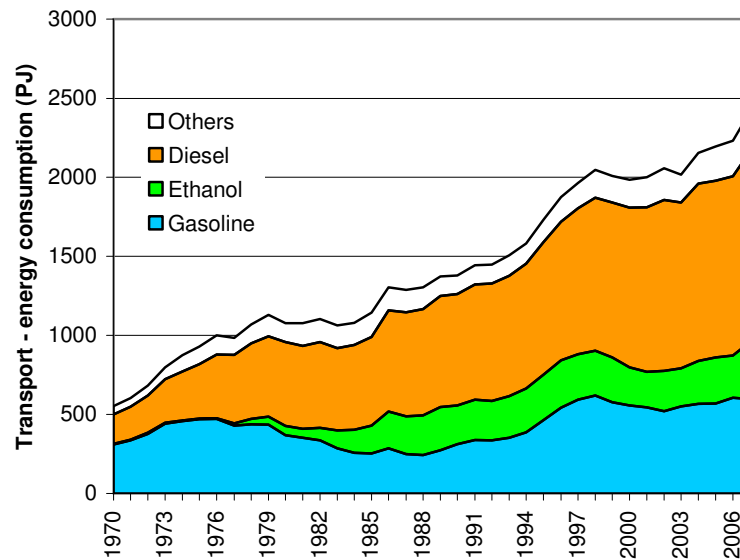
Figure 1.10 shows the structure of final energy consumption in the industrial sector by 2007. The share of biomass would be reduced for 20% in case bagasse consumption is not considered. Details of the energy consumption in the industrial sector from 2000 to 2007 are presented in Annex A.



Source: EPE/MME (2008)

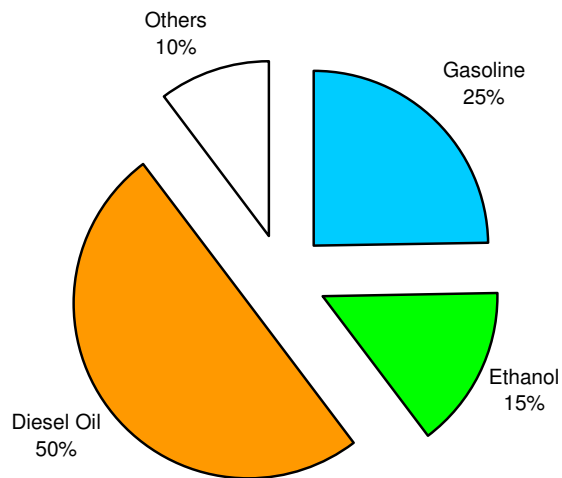
Figure 1.10. Final energy consumption in the industrial sector by 2007

For the transport sector, the evolution of the final energy consumption is shown in Figure 1.11. The growth of ethanol consumption (anhydrous ethanol, blended with gasoline, and hydrated ethanol) is remarkable since 1976. By 2007, ethanol consumption represented 16.3% of the energy consumption in road transportation and 34.2% of the energy consumption in spark-ignition vehicles (37.6% of the gasoline consumption in energy basis, and almost 47% in volume basis). In Figure 1.11, "Others" correspond mostly to kerosene (consumed in jet engines) and natural gas (consumed in spark-ignition engines). Figure 1.12 shows the distribution of the energy consumption in the transport sector by 2007.



Source: EPE/MME (2008)

Figure 1.11. Energy consumption in the transport sector – Brazil, 1970-2007



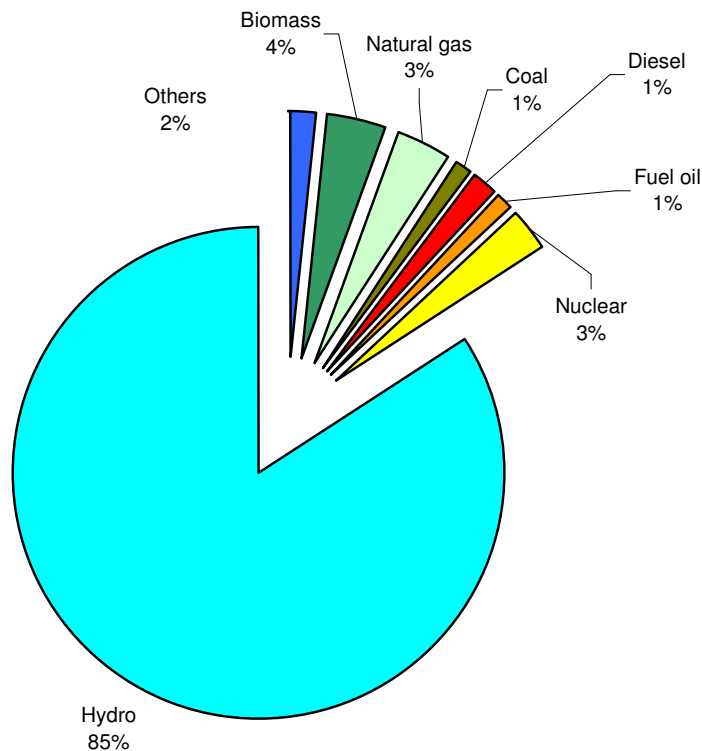
Source: EPE/MME (2008)

Figure 1.12. Final energy consumption in the transport sector by 2007

In Brazil, for more than five decades electricity production has been mostly based on hydro power plants. The bulk of the hydroelectric potential is still untapped (about 70%), but most of it is located in the North region (112 GW over 261 GW); it's going to be difficult to take full advantage of the remaining potential in the North region as, firstly, hydro power plants could cause large environmental impacts in the Amazon area and, secondly, the potential is far from the largest consumer markets (in Southeast and South regions).

Figure 1.13 shows the profile of electricity generation in 2007, when 85% of the generation was based on hydro power plants. Results presented in the figure corresponds to the production in Brazil; as previously mentioned, Itaipu belongs 50% to Brazil (50% belongs to Paraguay), and only the Brazilian share is included in this figure. Electricity generation in Brazil summed-up 444.6 TWh in 2007, while imports (mostly from Itaipu) summed-up 40.9 TWh in the same year.

Regarding the installed capacity of electricity production, by mid-2007 hydro power plants corresponded to almost 73% of the total (also excluding 50% of the Itaipu's capacity). Only 5% of the installed capacity is based on thermal power units based on biomass. Table 1.2 shows the current profile of the installed capacity of electricity production and Table 1.3 shows the profile of electricity production based on biomass; it can be seen that most of biomass power capacity corresponds to cogeneration from sugarcane residues (bagasse) and black-liquor.



Source: EPE/MME (2008)

Figure 1.13. Profile of electricity generation by 2007

Table 1.2. Profile of the installed capacity of electricity generation by June 2009

	Capacity (MW)	Share (%)	Number of plants
Hydro – large-scale	74,701	70.1	159
Hydro – small-scale	2,817	2.6	343
Thermal- conventional	26,679	25.0	1,245
Nuclear	2,007	1.9	2
Wind	417	0.4	33
Solar	0	0.0	1
Total	106,621		1,783

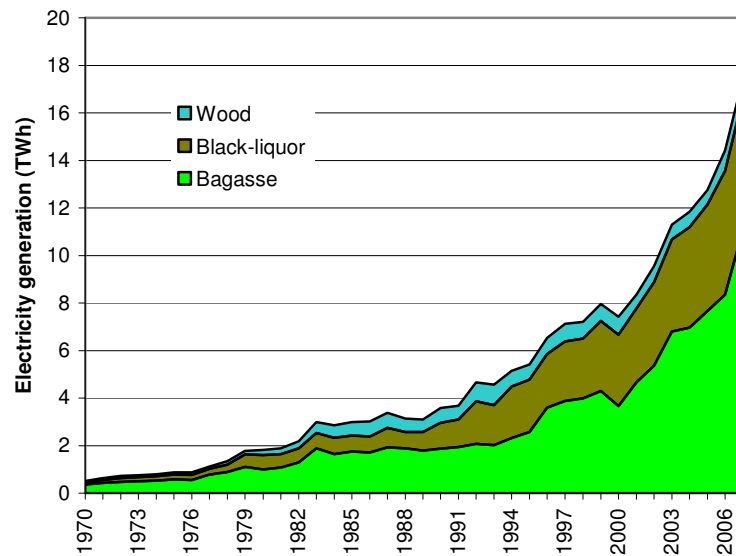
Source: ANEEL (2009)

Figure 1.14 shows the growth of electricity production (since 1970) from the most important biomass sources. In recent years, about 40% of the electricity produced from bagasse has been commercialised with the grid; the bulk of electricity production from biomass is consumed in the industrial processes where the cogeneration units are located. Figure 1.15 shows how the share of electricity production from biomass has grown since 1970.

Table 1.3. Profile of thermal power plants based on biomass by June 2009

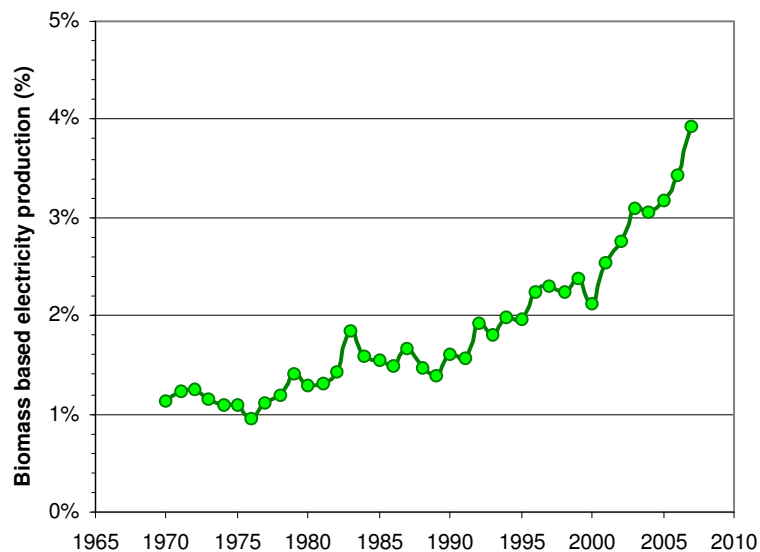
	Capacity (MW)	Share (%)	Number of power plants
Sugarcane residues	3,957	72.7	270
Black liquor	1,146	21.1	14
Wood residues	240	4.4	29
Biogas	42	0.8	7
Rice residues	31	0.6	7
Charcoal	25	0.5	3
Total	5,441		330

Source: ANEEL (2009)



Source: EPE/MME (2008)

Figure 1.14. Electricity production from biomass – 1970-2007



Source: EPE/MME (2008)

Figure 1.15. Electricity production from biomass over the total (only 50% of Itaipu is included)

1.3 Greenhouse gas emissions

Brazil is not an Annex I country in the Kyoto Protocol and, thus, does not have commitments regarding emission reductions for the period 2008-2012. Not considering greenhouse gas (GHG) emissions due to land use change and deforestation (LULUCF), the emissions of carbon dioxide in Brazil, in 2004, were estimated as 331.6 MtCO₂ (16th position worldwide) (209.5 MtCO₂ in 1990;

22nd position worldwide) (UNDP, 2009)⁴⁵. However, taking into account LULUCF emissions, Brazil moves to the 5th position, being responsible for 5.3% of the total GHG emissions in 2000 (after United States, China, EU25 and Indonesia), with 2,322 MtCO_{2eq} (WRI/CAIT, 2008).

Worldwide, it is estimated that Brazil has the largest stock of carbon in forests (49,335 MtC), 1.5 times larger than Russian Federation (the second largest stock holder) and 2.6 times larger than United States (the fourth largest stock holder) (UNDP, 2009).

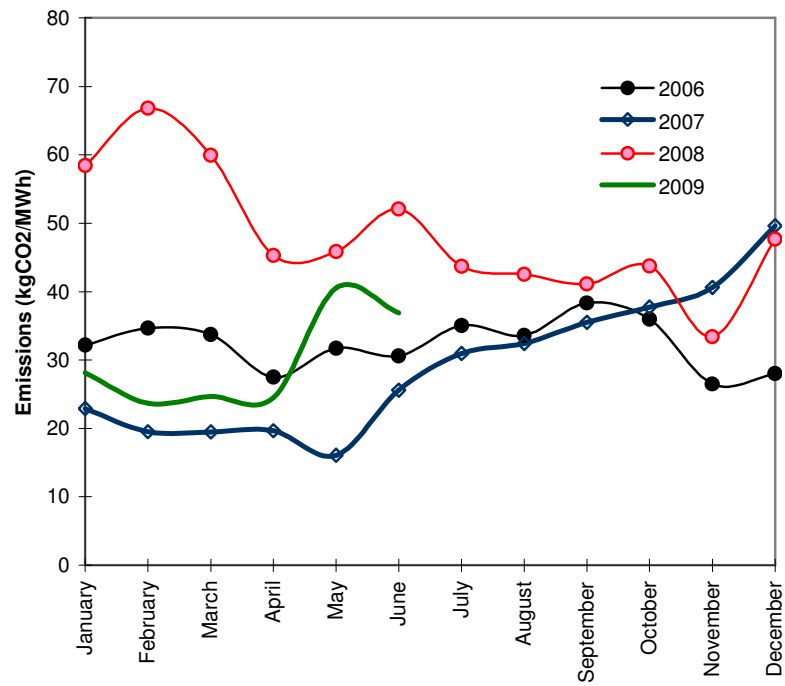
Brazil has released only one official survey of GHG emissions, based on data of year 1994. According to this study, the emissions due to land use change and deforestation in Brazil covered that year almost 55% of the total emissions (818 over 1,477 MtCO₂), with 25% due to the agriculture and 17% due to energy production and use. The balance was due to the emissions in industry (2%) and due to waste disposal (1%) (Brasil, 2004).

Emissions of CO₂ per head due to energy consumption were 1.8 tonnes/habitant in 2004 (1.4 t/head in 1990), while the figure for carbon intensity of growth was 0.24 ktCO₂/million US\$ PPP (2000) in 2004 (0.22 ktCO₂/million US\$ PPP (2000) in 1990) (UNDP, 2009). These figures are very low in comparison with other countries (developed and developing countries).

Regarding electricity generation in the Brazilian national interconnected system, the average CO₂ emission factors from January 2006 to June 2009 are presented in Figure 1.16. The evaluation is based on fuel consumption and on the hypothesis that hydro power plants do not cause GEE emissions. Due to the profile of electricity generation in Brazil, the estimated CO₂ emissions are quite low.

⁴ Emissions due to the consumption of fossil fuels, gas flaring and cement production.

⁵ According to WRI/CAIT (2008), GHG emissions of Brazil (not-considering LULUCF) were estimated as 346.6 MtCO₂ in 2004 that put Brazil in 19th position among the top emissors (being responsible for 1.2% of total emissions that year).



Source: MCT (2009)

Figure 1.16. CO₂ emission factors in the Brazilian national interconnected system

2. Energy Policies

2.1 Ethanol⁶

The so-called chicken and egg problem is classical for alternative fuel vehicles: who will buy them if a fuelling infrastructure is not in place, and who will build the infrastructure if there is no vehicles in the market? (Romm, 2006). There is high-risk perception both for producers and consumers, and this is one of the main challenges for deploying an energy source.

During the first 15 years of the Brazilian ethanol program, supply and demand were both stimulated and adjusted through central coordination. Producers accept the Program since the very beginning as it was also created in order to minimize the difficulties frequently faced by sugarcane sector due to the excess of sugar production and fluctuations of its international prices. In addition, the required investment was assured by credits given at low interest rates and risks were extremely reduced as sales were guaranteed and prices were controlled – both to sugarcane and to ethanol. In fact, fixed prices for producers and consumers played an essential role in the general trust of the program (van den Wall Bake et al., 2008).

Also aiming at assuring the supply, the government has obliged the state-controlled oil company (PETROBRAS) to provide and operate the required infrastructure of transport, storage, blending and distribution. Eventual losses during ethanol commercialisation were also assumed by PETROBRAS.

In parallel, in order to induce the consumption, the government negotiated with the automobile industry⁷ to introduce the required modifications in engines and parts. More modifications are required as large is the share of ethanol in the fuel blend⁸ (Coelho et al., 2006). In early 1980s, the automobile industry has accepted to give full warranties to the consumers. The R&D efforts regarding engines able to run with blends and straight ethanol started at a federal research centre (Aeronautics Research Centre) where the development of engines and tests were performed. The first neat ethanol engine was commercially available in 1979 and technology was quickly transferred to the automobile industry.

On the other hand, the ethanol market was induced by mandates. In 1975, a mandate for 20% anhydrous ethanol (E20 – volume basis) on fuel blend was established. However, just by early 1980s the share of ethanol into all gasoline commercialised reached 20 %. Through the years, the share of ethanol in fuel blend has changed, as can be seen in Figure 2.1. The ethanol share was reduced to 13% between 1989 and 1993, during a (domestic) supply ethanol crisis, while in 1993 it was defined by law that the share of ethanol in fuel blend should be in the 15–25% range, depending on the conditions of ethanol market. Since then the lowest level reached was 20%. In practice, this relative wide range allows the shift of production to more sugar (when it is convenient), allowing the producer to maximize its earnings. Currently, the share of anhydrous ethanol in the fuel blend is 25%.

⁶ Text based on Walter (2008): Bio-ethanol Development(s) in Brazil; in: Soetaert W. and Vandamme E. (Editors). Biofuels.

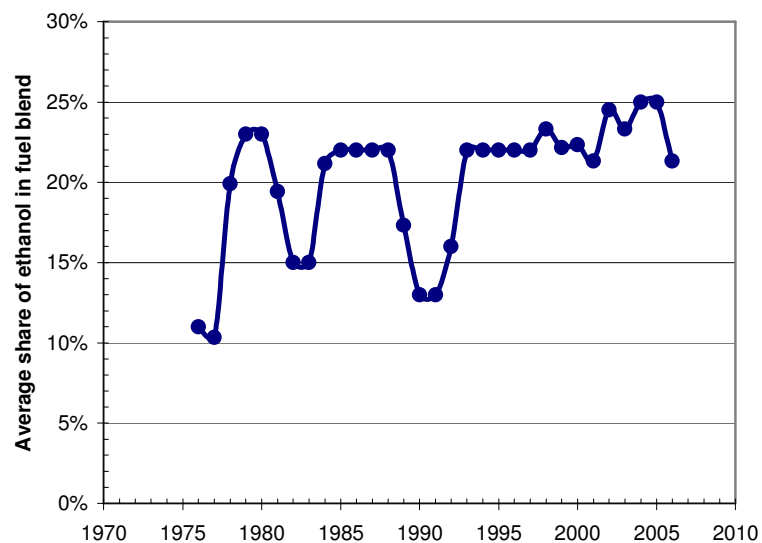
⁷ At that time, four main companies were based in the country.

⁸ For instance, for 25–100% ethanol in the fuel blend, modifications include materials substitution (e.g. of the fuel tank, fuel pump, electronic fuel injection system) and new calibration of devices (e.g. of ignition and electronic fuel injection systems).

Moreover, along the years consumers were stimulated to buy neat-ethanol cars through lower taxes regarding those applied over gasoline vehicles. In addition, fuel prices were controlled until mid 1990s and ethanol prices to consumers were kept close to 65 % of the gasoline's price (volume basis).

In Brazil, taxes have a strong impact over the consumer's fuel price. Currently, six different taxes and contributions have been applied over automotive fuels, being just one equivalent to the value-added tax (VAT). For instance, in 2005, the average taxation over gasoline C (gasoline blended with ethanol) in Brazil was estimated as 47%, while the average taxation over hydrated ethanol was evaluated as 34%. In addition, in state of São Paulo (the largest producer and consumer of ethanol in Brazil), the taxation over hydrated ethanol was close to 20% in the same year (Cavalcanti, 2006). In the state of São Paulo an additional advantage for ethanol consumers is the lower value of the annual license paid by owners of neat-ethanol vehicles (including FFVs).

Direct subsidies were completely eliminated with the deregulation process that finished in early 2000s. However, a tax exemption policy is in place and part of the benefits received by ethanol consumers is due to lower taxes applied to ethanol regarding those paid by gasoline consumers. Anyhow, it should be noticed that in Brazil the taxation applied to diesel oil is even lower than the correspondent applied to ethanol (about 27 % in 2005, on average) (Cavalcanti, 2006).



Source: F.O. Lichts (2006)

Figure 2.1. Average share of ethanol (anhydrous) in the fuel blend, according to mandates

2.2 Biodiesel

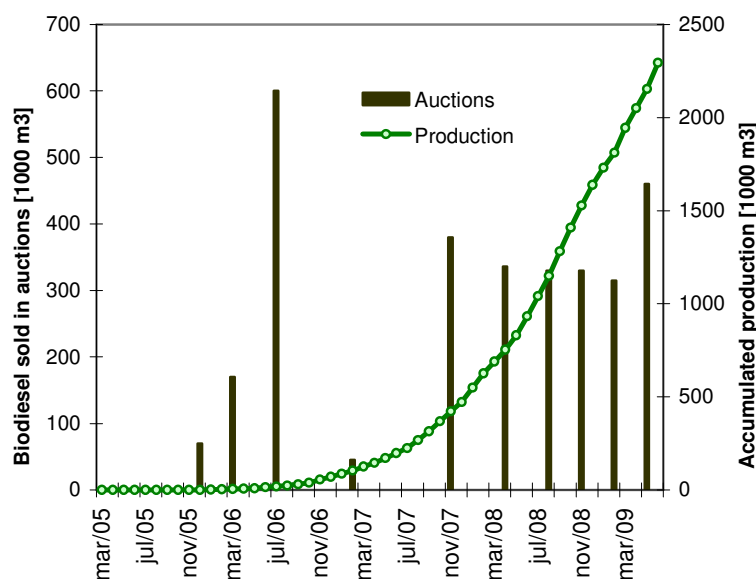
By the end of 2004, Brazilian government decided to implement the so-called National Program of Biodiesel Production and Use (PNPB). The declared targets of the program are generating jobs and income in rural areas and reducing regional inequalities. According to the government, two additional targets are the potential contribution to foreign-exchange savings and environment improvements.

In 2004 it was defined by law that B2 blends would be mandatory countrywide from January 2008, but this target was increased to B3 blends in July 2008 and enlarged to B4 blends in July 2009. In January 2013, the mandatory mix will increase to 5% of biodiesel (B5), but probably this target will be brought forward to 2010. Higher biodiesel blends or even B100 can be used, but only if authorized by the Petroleum, Natural Gas and Biofuels National Agency (ANP). From 2005 to 2007, the use of B2 blends was not mandatory.

The program was conceived in order to foster the production of biodiesel from different raw materials, such as palm oil and babassu in the North region, castor oil and cottonseed in Northeast region, sunflower and peanuts in the South and soybeans, residual oil and fats in the Southeast and Centre regions. However, the bulk of biodiesel production has been based on soy oil.

The three main pillars of the PNPB are: the so-called “Social Label”, as specific policies were designed to support subsistence farming systems; reduction of some federal taxes; and biodiesel purchasing auction schemes (Amaral et al., 2008).

The production of biodiesel has been encouraged through purchase auctions organized by ANP. Fourteen auctions took place since 2007 while the total amount of biodiesel sold almost surpassed 3 BL. Only producers that hold the Social Label (see below) can participate on these auctions; PETROBRAS assures the purchase (Pousa et al., 2007). Figure 2.2 shows the volume of biodiesel sold in auctions and the accumulated production from mid-2005 to April 2009.



Source: ANP (2009)

Figure 2.2. Biodiesel sold and accumulated production, 2005 - onwards

The engagement of small farmers and producers of the poorest regions in the biodiesel value chain has been fostered by means of tax incentives granted to firms that purchase oil-producing crops grown by small farmers. Total or partial taxes exemptions are granted to biodiesel producers that support family farming. Producers that acquire raw material from family farmers, anywhere in

Brazil, are eligible to reduction of up to 68% in federal taxes. If these purchases are made from family-based producers of palm oil in the North Region or of castor oil in the Northeast and in the Semi-Arid Region (Northeast and Centre regions), the reduction may reach 100%. If producers are not family farmers, the maximum reduction is of 31%.

In order to qualify for these tax benefits, biodiesel producers have to hold a certificate, called Social Label. The Ministry of Agrarian Development (MDA) issues the Social Label to biodiesel producers provided that they meet the following requirements:

- a) Purchase of minimum percentages of raw materials from family farmers (10% in regions North and Mid-West, 30% in South and Southeast regions and 50% in Northeast and Semi-Arid Regions); and
- b) Contracts with family farmers establishing deadlines and conditions of delivery of the raw material (including prices) and provision of technical assistance to the family farmers.

2.3. Wood resources

In 1965, the existence of just 0.5 Mha 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 but failed on the target of planting additional 6.5 Mha.

In the 1990s the increment on forested area was reduced from about 300,000 ha/year to about 170,000 ha/year. Two industrial branches (pulp and steel industries) were responsible for most of those plantings, with improvement on wood yields through development and use of new technologies. During the first half of the 2000s, forested areas held about 250,000 ha/year, an amount still lower at that time than the harvested area. Some timber consumers, that faced most of the supply problems, imported wood from MERCOSUR countries.

Several forestry programs have been implemented, such as Pronaf Florestal (Forestry Program for Familiar Agriculture Support), Propflora, Profloresta, and Proambiente. They have acted increasing annual planted forests through funding 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 were additional 0.8 Mha through small and medium farmers and 1.2 Mha through medium and large companies. For native forests, in the same period the targets included certification and sustainable management of 15 Mha of native forests, being 5 Mha planted and managed by communities or families.

Regarding programs aiming at foster the demand of solid biomass in industries, it should be mentioned a government action in the 1980s that induce the use of charcoal as substitute of imported coal and coke. The peak of charcoal output was in 1989 (about 240 PJ), when almost 40 per cent of the pig-iron production was based on this biomass source. During the 1990s large-scale integrated steel mills shifted again their energy matrix, returning to coke due to its reducing costs. Currently, charcoal use in pig-iron production is concentrated in small independent factories.

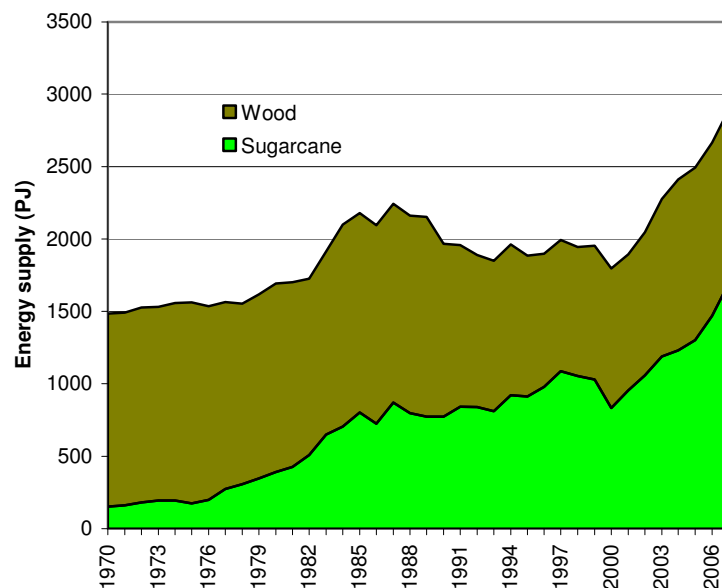
Also in the first half of the 1980s, federal government induced the use of firewood targeting the substitution of fuel oil in industries. The peak of firewood consumption was in 1986, when it

reached 280 PJ, and after that it continuously declined down to about 200 PJ in 1992; consumption surpassed 250 PJ in 2007.

3. Biomass Resources

Currently, the main biomass resources in Brazil are wood, sugarcane and the oil seeds used for biodiesel production; the most important oil seed so far is soybeans. In 2007, the contribution of wood and sugarcane to the total energy supply was 2,783 PJ, or 30.9% of the total (being 12.8% from wood and 18.1% from current sugarcane products – ethanol and bagasse)⁹. As shown in Figure 1.5, the contribution of biomass sources to the final energy consumption in 2007 reached 2,350 PJ, or 29.3% of the energy consumption; sugarcane bagasse (1,120 PJ), firewood (683 PJ) and ethanol (281 PJ) are the main biomass energy sources.

Sugarcane has consolidated its position as the main biomass source in Brazil in recent years. Its importance is due to the production of ethanol (hydrated and anhydrous), that occurs with the use of sugarcane bagasse as fuel in cogeneration systems. Sugarcane is also important due to the production of sugar (that also uses sugarcane bagasse as fuel). In fact, most of the sugarcane mills in Brazil produce both ethanol and sugar (see section 4.2), but from the point of view of statistics, ethanol production is dealt within the transformation sector and sugar production in the food and beverage sector. Figure 3.1 shows the evolution of sugarcane and wood supply from 1979 to 2007.



Source: EPE/MME (2008)

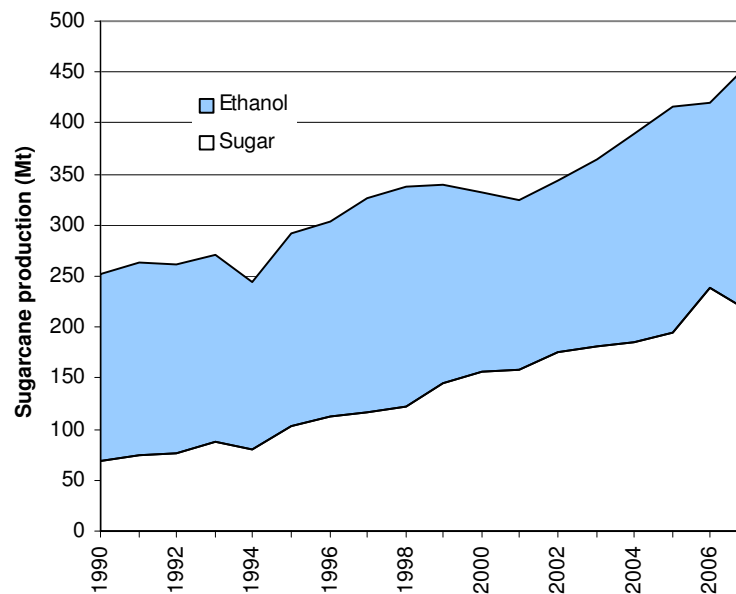
Figure 3.1. Supply of sugarcane and wood from 1970 to 2007

3.1 Sugarcane

Sugarcane is a traditional crop in Brazil. Its use for fuel ethanol production in large-scale started in 1975 (see section 4.2); previously to that, sugarcane was mainly used for sugar and ethanol production for other uses (e.g., industrial).

⁹ The last issue of the Brazilian Energy Balance (EPE-MME, 2008) does not present data about biodiesel production for the years 2006 and 2007.

Figure 3.2 shows the growth of sugarcane production for sugar and ethanol from the harvest season 1990-1991 to 2007-2008. Up to early 2000s, there was a growth on the share of sugarcane used for sugar production, with a change of this tendency afterwards. On average, during the five last harvest seasons half of sugarcane was used for sugar and half for ethanol production.



Source: MAPA (2008)

Figure 3.2. Sugarcane used for sugar and ethanol production from harvest season 1990-1991 to 2006-2007 (based on the amount of sucrose used for each product)

The bulk of sugarcane production is in state of São Paulo, with about 60% of the total production in 2007; in the Centre-South region the concentration reached more than 87% that year. Regarding ethanol production, the concentration in the Centre-South region is even larger (90% in 2007), being almost 60% of the total production in state of São Paulo; Minas Gerais and Paraná contributed that year with almost equal shares (8.3%-7.9%) regarding the total national production (UNICA, 2009). A small share of sugarcane production is in the North-Northeast region (13%, being more than 10% in the Northeast region).

Sugarcane bagasse is derived from the fibres of the sugarcane plant. On average, sugarcane has 13-14% of fibres that implies the availability of 260-280 kg of bagasse per tonne of sugarcane crushed, with 50% moisture (absolute). Currently, most of the sugarcane bagasse is burned for steam raising at the mill site; bagasse use as fuel in other industrial branches is constrained by its low density, the low price of fuel oil and the distance between industrial plants. As the market opportunities are constrained, bagasse is inefficiently used at fuel; at least 50% of the bagasse could be saved in an efficient industrial unit.

The availability of sugarcane trash (leaves and points of the sugarcane plant) at the field is almost equal than bagasse, but so far almost no trash has been used as fuel. Traditionally, sugarcane fields are burned before harvesting in order to make manual practice easier and, hence, trash is completely

eliminated. Due to environmental reasons the tendency is the phase-out of sugarcane burning, and trash could be available for used as fuel. In Brazil, the average availability is 140 kg_{dry} of trash per tonne of sugarcane; it is estimated that up to 50% of the trash could be recovered and transported to be used as fuel at the mill site, while the balance should be left in the field for soil and plant protection.

In the future, sugarcane bagasse should be used as raw material for biofuels production from hydrolysis or gasification, or even for the production of chemicals.

3.2 Oil seeds¹⁰

Despite its favourable conditions and large agricultural tradition, Brazil is not among the major producers of vegetable oils, except soy oil (and to a lesser extent cottonseed). Table 3.1 shows production data of different vegetable oils from 2002 to 2007 and their share regarding Brazilian and world production. As can be seen, soybean oil represents almost 90% of the total domestic production of vegetable oils.

Table 3.1. Production of vegetable oils in Brazil and their share, and world production (of vegetable oils) – 2002-2007

Vegetable oils/data	2002	2003	2004	2005	2006	2007
Soybeans (1,000 tonnes) ¹	5,105	5,636	5,630	5,430	5,970	6,110
(% of world production of this oil) ²	16.8	18.9	17.3	15.7	16.4	16.3
(% of Brazilian production of VO) ³	77.8	88.3	90.1	89.2	89.9	n.a.
Cottonseed (1,000 tonnes) ⁴	196	217	264	257	242	n.a.
(% of world production of this oil)	5.6	5.7	5.5	5.6	5.0	n.a.
(% of Brazilian production of VO)	3.0	3.4	4.2	4.2	3.6	n.a.
Palm-oil (1,000 tonnes) ⁴	118	129	142	160	170	n.a.
(% of world production of this oil)	0.4	0.4	0.4	0.4	0.5	n.a.
(% of Brazilian production of VO)	1.8	2.0	2.3	2.6	2.6	n.a.

Sources: ¹ production data from USDA – Foreign Agricultural Series (FAS-USDA, 2008)

² calculated regarding world production taken from USDA – Foreign Agricultural Series

³ calculated regarding data Oil World, apud ABIOVE (2008), considering soy oil production from USDA

⁴ Oil World, apud ABIOVE (2008)

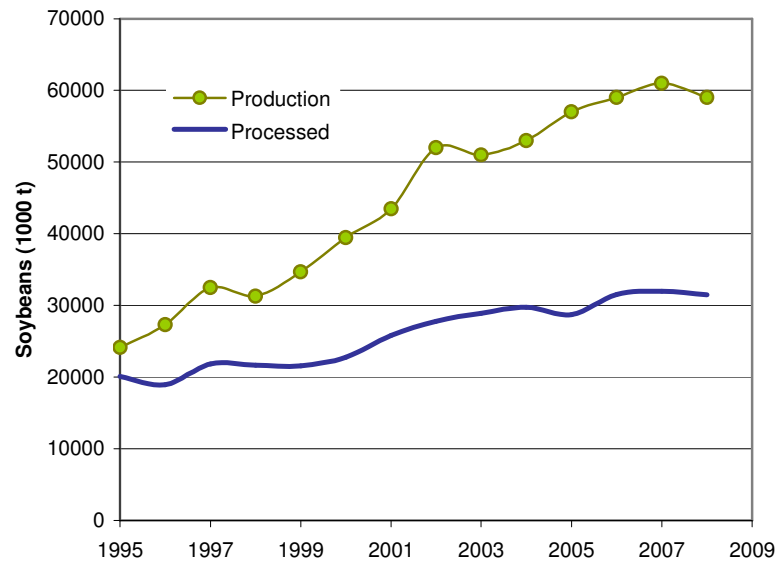
Notes: na = data not available.

VO = vegetable oils.

Brazil has a long tradition with soybeans production and is currently the second largest producer (after US). Regarding soy oil, in 2008 Brazil was the fourth largest producer, after US, China and Argentina. Figure 3.3 shows the evolution of soybeans production in Brazil in the period 1995-2008 and also shows the amount of the seeds production locally crushed; as can be seen, the production grew almost continuously but the share locally processed didn't grow as fast. In fact, the production locally crushed declined from 90% in 1995 to less than 60% in 2005-2008. This explains the lower importance of Brazil as soy oil producer.

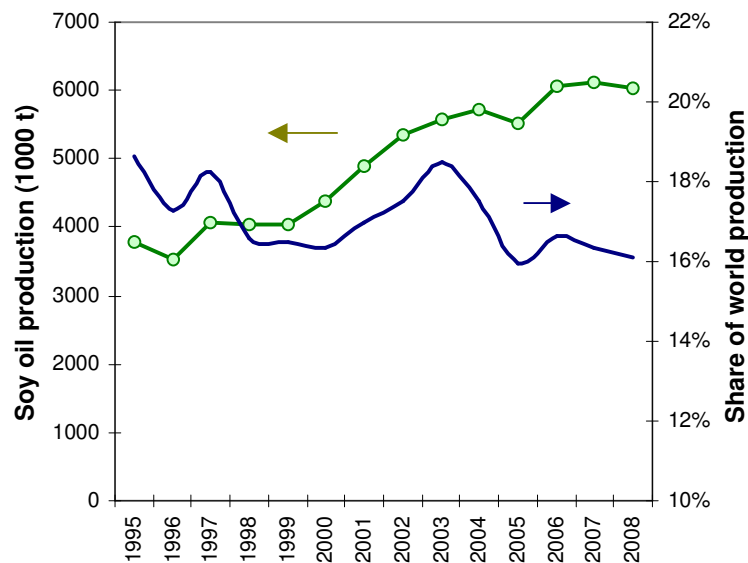
¹⁰ This section is based on Rosillo-Calle et al. (2009).

As an illustration, Figure 3.4 shows the evolution of soy oil production and its share regarding the world production.



Source: FAS-USDA (2009)

Figure 3.3. Soybeans production and production locally crushed from 1995 to 2008



Source: FAS-USDA (2009)

Figure 3.4. Soy oil production in Brazil and its share regarding the world production

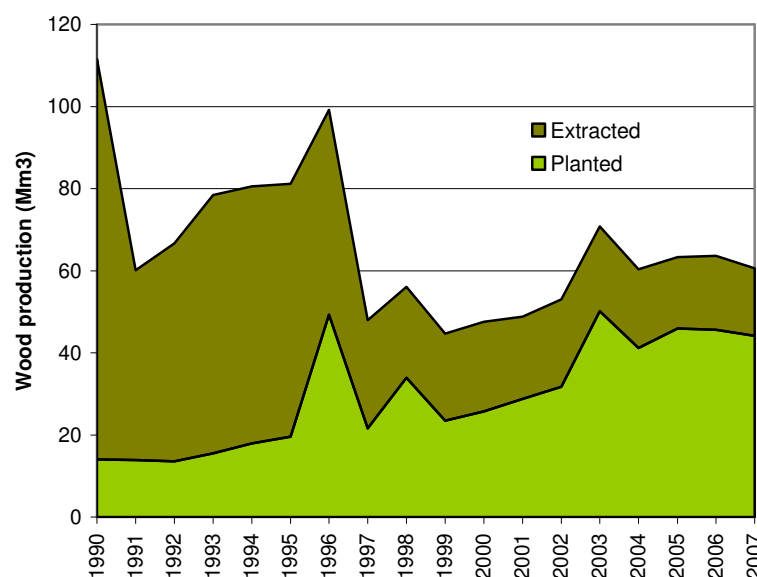
The production of soybeans in Brazil has been blamed for deforestation, due to the fact that the recent expansion of this crop has been in the Cerrado region, in the central part of Brazil. It is

believed that soybeans expansion has caused deforestation in that area (i.e., directly causing land use change) and has indirectly contributed to the deforestation in the south of Amazon region (i.e., causing ILUC). Soybeans occupy about 25 Mha in Brazil, and is the largest crop in the country, covering about 30% of the land occupied with agriculture.

3.3 Forestry resources

Wood production is a well-established activity in Brazil. Forest activities are concentrated both in the North and in the South regions. In the North region the production is mainly based on extrativism, while in the South planted forests are dominant, based on short-rotation coppices. Official data regarding wood production shows that the production based on extrativism for timber and logs has been reduced (e.g., in the period 1990-2007) (IBGE, 2009b). The production of dedicated forests aims at the pulp and paper industry, timber and logs production, and in a small extent charcoal production¹¹. Dedicated forests are mainly of pines and eucalyptus; being estimate as 4.3 Mha planted with eucalyptus and 1.9 Mha with pines (ABRAF, 2009).

Figure 3.5 shows the evolution of wood production mostly for timber and logs, based on extrativism and on dedicated forests, in the period 1990-2007; the information is based on surveys by IBGE, and is an estimate, mainly regarding the extrativist activity¹². Data are presented in Annex.



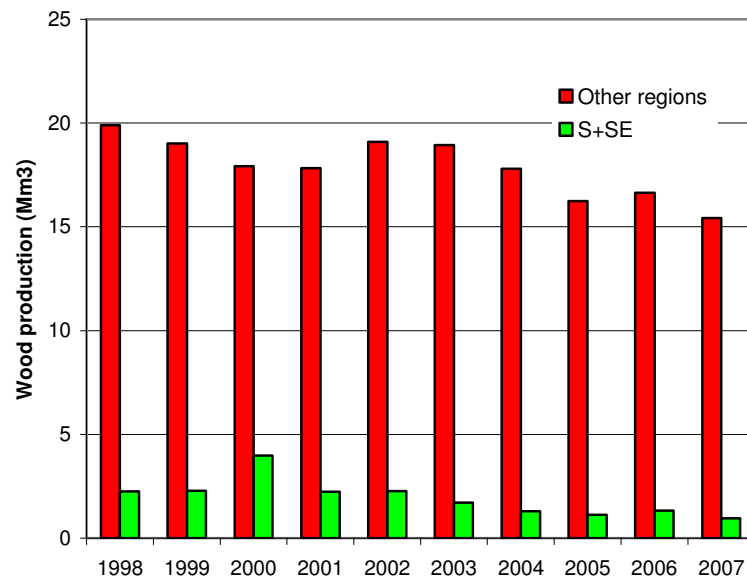
Source: IBGE (2009b)

Figure 3.5. Estimates of wood production in Brazil – 1990-2007

¹¹ According to the IBGE data (IBGE, 2009b), 38% of the wood production based on dedicated forests is used in pulp and paper industry, 28% for timber and logs, 24% as firewood, and 10% for charcoal production.

¹² Besides the intrinsic imprecision of such surveys, there is also illegal activity based on deforestation, mainly in the North region.

Figures 3.6 and 3.7 shows the evolution of wood production mostly for timber and logs, based on extrativism and on dedicated forests, respectively, in regions South + Southeast (S+SE) and other regions of Brazil. Production based on extrativism mostly occurs in the North region (72% in 2007; and mostly in Amazon region), and has declined in recent years (based on estimates by IBGE, reduction was about 10% per year, on average, in the period 1990-2007, and about 1.5% per year in the period 1998-2007).



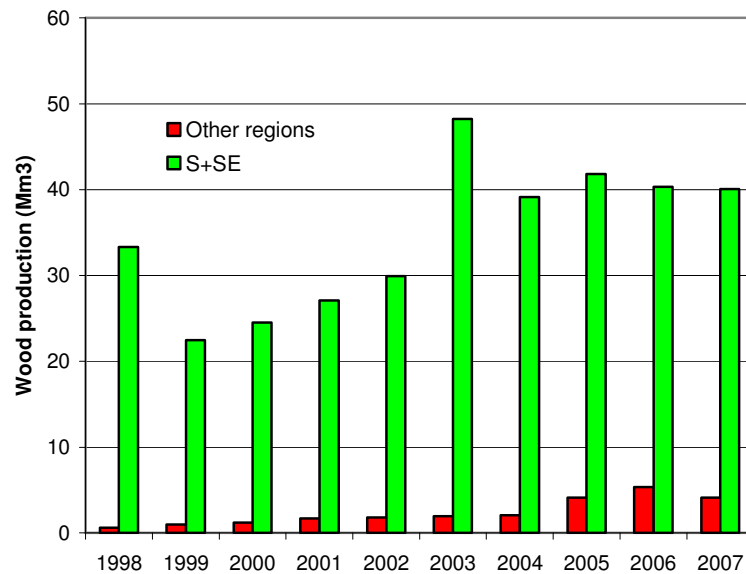
Source: IBGE (2009b)

Note: S+SE = South + Southeast regions

Figure 3.6. Estimates of wood production based on extrativism – 1998-2007

As can be seen in Figure 3.7, wood production based on planted forests mostly occur in the southern part of Brazil, and more specifically in the states of Paraná and Rio Grande do Sul (South region) and in state of São Paulo (Southeast region).

Particularly in case of dedicated forests of eucalyptus, it is believed that Brazil has worldwide the best technology for implementing them. Eucalyptus plantations have been condemned for years, but some of the constraints of the past are no longer a matter of concern (e.g., soil drainage, soil degradation, nutrient leaching and reduction of water storage capacity can be almost completely avoided if adequate techniques are applied). Regarding biodiversity preservation, the usual solution is both to form and maintain wildlife corridors connecting areas under conservation (native vegetation) (Couto *et al.*, 2002).



Source: IBGE (2009b)

Note: S+SE = South + Southeast regions

Figure 3.7. Estimates of wood production based on planted forests – 1998-2007

In Brazil, the forestry sector tends to expand occupying land currently used for several other activities, mainly pasturelands. Among them are the so-called second-class lands, notably those with poor chemical (fertility, cationic exchange capacity) and physical characteristics (texture, depth, drainage), and with high slopes; some of these lands are under a degradation stage. Shifting on land use towards to forest is also happening on orange and coffee fields where both soil and topography use to have better quality. Only in 2006-2007 season, the additional area planted with forests was about 0.6 Mha. The location of planted forests inside country may be seen in the Figure 3.8. The average annual increments observed in 2006 were $27 \text{ m}^3 \cdot (\text{ha} \cdot \text{yr})^{-1}$ for pine and $38 \text{ m}^3 \cdot (\text{ha} \cdot \text{yr})^{-1}$ for eucalypt plantations (ABRAF, 2007).



Source: AMS (2007)

Note: light green: regions with eucalypt plantations; dark green: regions with eucalypt and pine plantations

Figure 3.8. Location of eucalypt and pine plantations in Brazil in 2006

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

4. Current and Expected Future Energy Use of Biomass

4.1 Ethanol – current production and perspectives

Worldwide, fuel ethanol consumption in 2008 was estimated as about 67 billion litres (REN21, 2009). Brazil is worldwide the second largest ethanol producer¹³; in the harvest season 2008-2009 its production reached 27.7 billion litres, while the domestic consumption as fuel was close to 20 billion litres (MAPA, 2009). All motor gasoline sold in Brazil contains 20-25% ethanol on volume basis (E20–E25). Neat ethanol vehicles use hydrated ethanol, while anhydrous ethanol is blended with gasoline.

Large-scale production of fuel ethanol in Brazil started in 1976 but it has been since 1999, after the complete deregulation of the industry, that the consumption has risen steadily. Flex-fuel vehicles (FFVs)¹⁴ have been the main driving force of the domestic consumption of ethanol. In Brazil, FFVs can run with any fuel mix between gasohol (E20–E25) and pure hydrated ethanol (E100). The relative low price of ethanol regarding gasoline, and the good technology of FFVs, are the main reasons why currently they are more than 90% of the new cars in Brazil. It is estimated that FFVs reached 32% of the fleet of light vehicles in mid-2009 (MME, 2009) and possibly will reach 65% by 2015 (Jank, 2008).

Since early 1980s, all ethanol production in Brazil is based on sugarcane. In addition to the favourable conditions for biofuels production, such as climate, rainfall, land availability and working force availability, Brazil has taken advantage of the long-term experience with sugarcane production. It is also worth to mention that during about 15-20 years (i.e., from 1975 to early 1990s) the Brazilian federal government offered very favourable conditions for fuel ethanol production (see section 2.1).

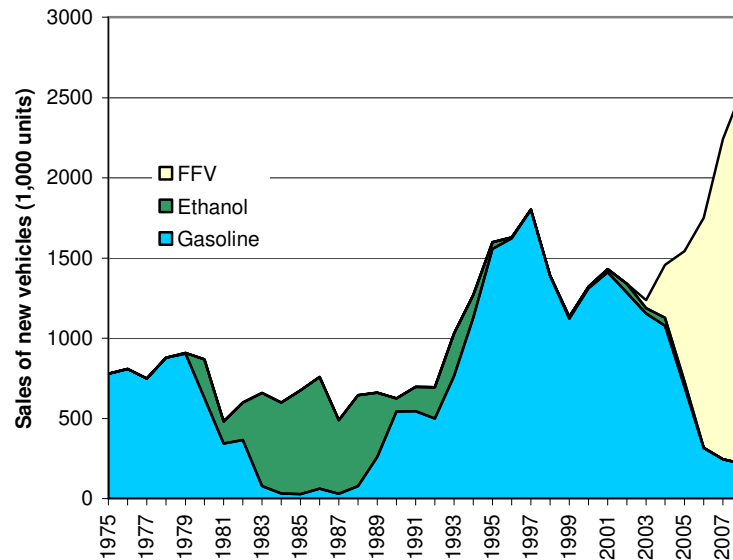
Brazilian experience with ethanol blended to gasoline comes back from the 1930s, but it was in 1975 that the Brazilian Alcohol Program (PROALCOOL) was created aiming at partially displacing gasoline in the individual transport. At that time, the country was strongly dependent on imported oil and gasoline was the main oil derivative consumed. In 1979, with the second oil shock, Brazilian Government has decided to enlarge the Program, supporting large-scale production of hydrated ethanol to be used as neat fuel in modified engines.

During the first period of the Program (1975-1979) ethanol production was accomplished by new distilleries annexed to the existing sugar mills, while in the period 1979-1985 many autonomous distilleries were built. It is estimated that at that time about US\$ 11-12 billion were invested to create a structure able to produce about 15 billion litres of ethanol per year.

Less support from the government and the lack of a positive attitude by the producers have laid the ethanol market to difficulties during the 1990s, starting with a shortage of ethanol supply in 1989-1990 that led to a strong drop in sales of neat ethanol cars. For instance, sales of neat ethanol vehicles that have reached 92-96% during the 1980s were continuously reduced until summing up just about 1,000 new vehicles per year in 1997-1998. The reduction of the neat ethanol fleet deeply impacted the consumption of hydrated ethanol during the 1990s and early 2000s. Figure 4.1 shows total sales of new vehicles in the period 1975-2007, according to the fuel option; with the success of FFVs, sales of straight-ethanol vehicles vanished in 2006.

¹³ Since 2006 US is the main world producer country.

¹⁴ The first model was launched in March 2003.



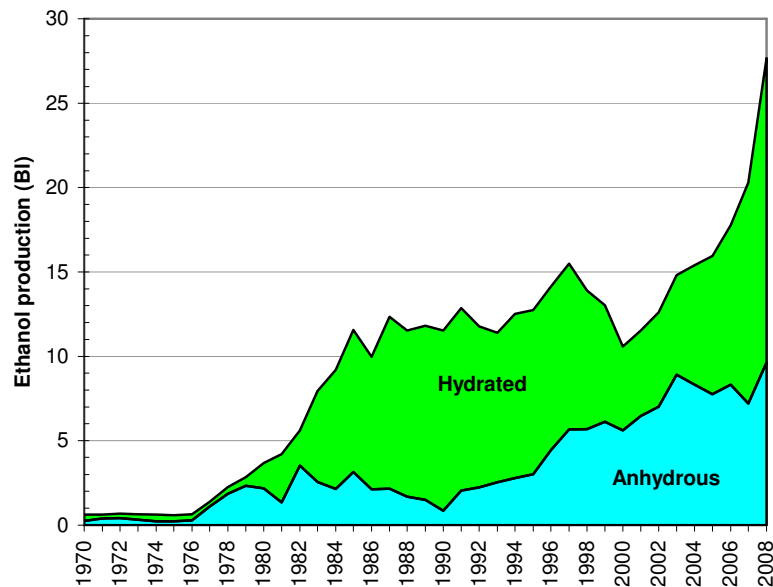
Source: ANFAVEA (2009)

Figure 4.1. Annual sales of new vehicles from 1975 to 2008, according to the fuel option

The PROALCOOL, as initially conceived, has finished during the 1990s as long as the government support has ceased. In fact, main changes started in early 1990s, first with liberalization of fuel prices to consumers and, second, in late 1990s, with full deregulation of sugarcane industry. The positive results started to be noticed in 2001, when sales of neat ethanol cars increased due to a larger price difference between ethanol and gasoline. However, as previously mentioned, since 2003 there is a boom on sales of vehicles able to run powered by ethanol (FFVs).

Due to the success of FFVs, it is predicted that the domestic market of ethanol shall reach almost 35 billion litres by 2015 and 50 billion litres by 2020. Currently ethanol (hydrated and anhydrous) covers almost 35% of the energy consumption of light-duty vehicles in Brazil. The tendency is that this share will grow in the years to come reaching about 50% (energy basis) in about 10 years.

Figure 4.2 shows ethanol production in Brazil from 1970 to 2008. The production in the harvest season 2008-2009 was 27.7 billion litres, while the domestic consumption reached almost 20 billion litres in 2008 (it was 18 billion litres in 2007). It is clear from Figure 3.2 that since 2003 (i.e., after FFVs) the production of hydrated ethanol has increased continuously while the production of anhydrous ethanol (exported and domestically used in fuel blends) has been almost constant.

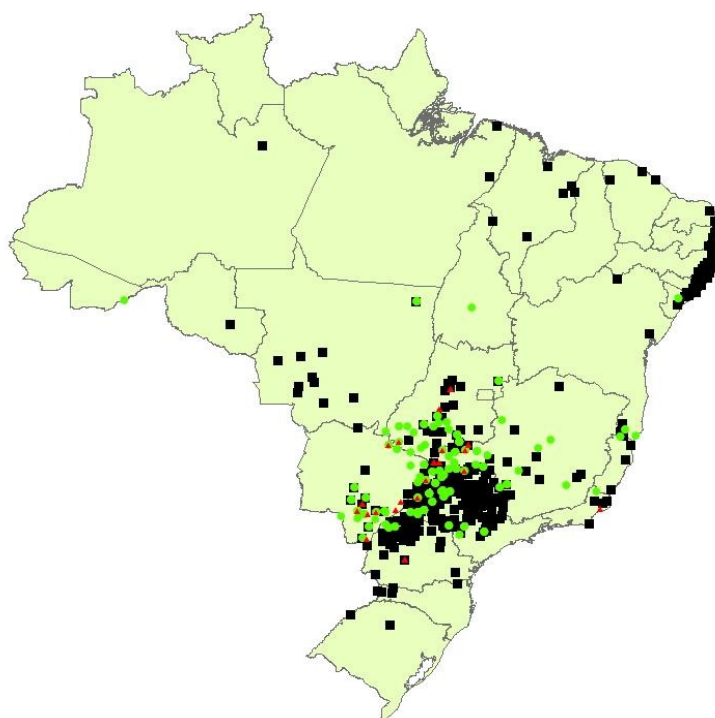


Source: EPE-MME (2008) and MAPA (2009)

Figure 4.2. Ethanol production in Brazil from 1970 to 2008

There are about 400 industrial units under operation and other 50-60 mills under construction or expected beginning of production between 2009 and 2011¹⁵. Figure 4.3 shows the location of sugarcane mills in Brazil by the end of 2008 (existing mills – black squares – and those planned to be built – green circles). It is estimated that 70-80% of the total production is in state of São Paulo and the regions around it. A small share of sugarcane production is in the North-Northeast region (13%, being more than 10% in the Northeast region). In 2008, the capacity of ethanol production was about 30 billion litres. From 2008 to 2012 about 33 US\$ billion should be invested, being 23 US\$ billion in new mills (Jank, 2008).

¹⁵ There is uncertainty regarding the units under construction as some predicted units could just correspond to projects.



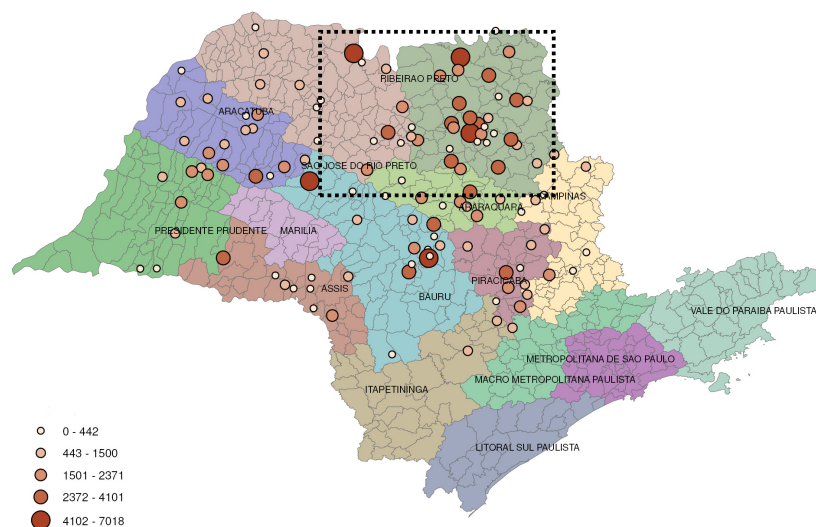
Source: EPE (2009)

Figure 4.3. Existing sugarcane mills and those predicted to be built

In 2007, 273 mills were able to produce both ethanol and sugar, with some degree of flexibility between the two products (general sense, the production varies from 40% to 60% ethanol, and consequently, 60% to 40% sugar), 77 mills were only able to produce ethanol (autonomous distilleries) and 16 mills were able to produce only sugar.¹⁶ "Brazilian model of ethanol production" refers to the combined production of sugar and ethanol, option that brings some advantages to producers, at least regarding risk reduction.

In the state of São Paulo, the region with highest concentration of sugarcane mills – Ribeirão Preto, indicated by dotted lines in Figure 4.4 – has the best conditions for this crop, considering soil quality, weather adequacy, rainfall and topography. This region has high concentration of sugarcane areas and land is relatively expensive there. In state of São Paulo the tendency is the installation of new producing units in the west side of the state, displacing pasture and, in a smaller extent, other traditional crops (e.g., orange). Besides the factors mentioned above, the concentration of sugarcane production in São Paulo and neighbourhoods is also due to the best infrastructure available there (including storage facilities, roads, pipelines, harbours, etc.), and the size of the consumer market.

¹⁶ By the end of September 2008, there was 414 sugarcane mills officially registered at the Ministry of Agriculture, being 248 mills with annexed distilleries, 151 mills with autonomous distilleries and 15 mills that can only produce sugar (MAPA, 2008).

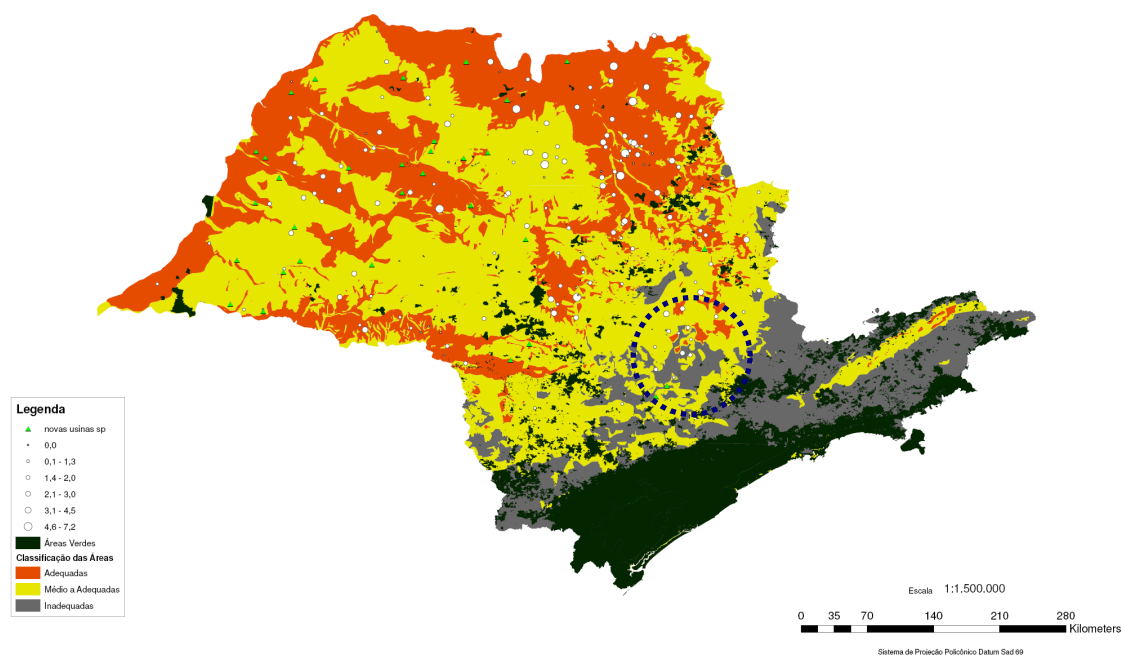


Source: Franco (2008)

Figure 4.4. Regions with sugarcane mills in state of São Paulo, in 2006 (circles represent the amount of sugarcane crushed per year in each mill – thousand tonnes)

In the harvest season 2008-2009 the planted area with sugarcane summed-up 8.4 Mha, allowing the production of 558 million tonnes. In 2006 sugarcane occupied 10% of the whole cultivated land in (about 77 Mha) (IBGE, 2008); by 2020, it is estimated that about 14 Mha would be occupied with sugarcane and the production shall reach 1,040 million tonnes (Desplechin, 2009).

Figure 4.5 is an illustration of the areas in state of São Paulo with adequate conditions for sugarcane production. Adequacy was defined as function of weather conditions, rainfall, soil quality, risk of erosion and topography. Not surprising, it can be seen that most of the mills already installed (white points in the figure) are located in most favourable areas. Some of the new mills are also being built (or are planned to be built) in these areas. However, considering topography constraints the traditional region of sugarcane production around Piracicaba can be classified as inadequate (identified by the dotted circle in Figure 4.5).



Source: Franco (2008)

Note: Most adequate areas are marked orange, medium-adequate areas are marked yellow, while inadequate areas are marked grey. Areas in dark green are areas with environmental constraints.

Figure 4.5. Adequacy of areas for sugarcane plantation in state of São Paulo.

Topography imposes important constraints for mechanical harvesting, that is a tendency in state of São Paulo as previous burning of the sugarcane field should be completely phased-out by 2017. Previous burning is still a common practice in Brazil in order to make feasible manual harvesting. Currently, mechanical harvesting is already cheaper than manual harvesting, but the required investments and topography are constraints in this process. In the state of São Paulo, in the last harvest season, about 50% of the sugarcane was harvested without previous burning. There are regions in the state (e.g., in Ribeirão Preto) where more than 90% of the sugarcane is harvested without burning (Jank and Rodrigues, 2008).

It is estimated that there are about 72,000 suppliers in Brazil (UNICA, 2009), being about 14 thousand in the state of São Paulo. Table 4.1 shows the profile of sugarcane suppliers in São Paulo, during the harvest 2006-2007.

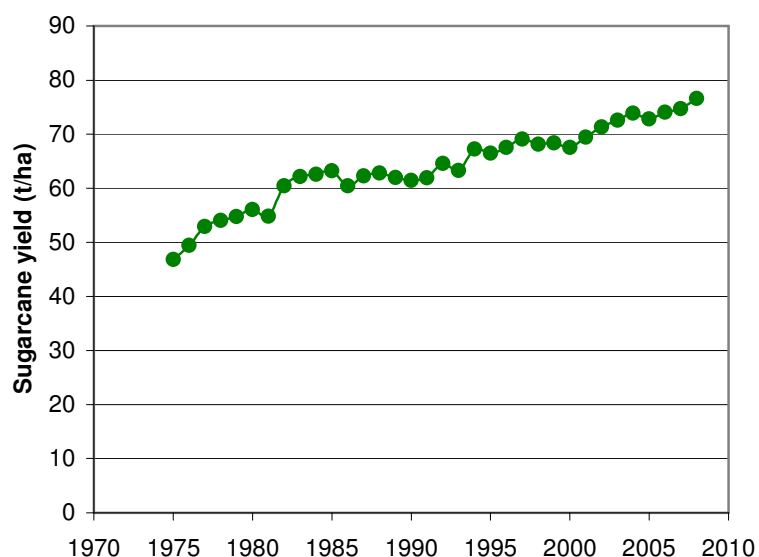
Table 4.1. Profile of sugarcane suppliers in the state of São Paulo – 2006-2007

Range of production (t)	Number of producers	% of producers	Average area (ha)	Production (1000 t)	% of production	Average yield (t/ha)
< 200	1,582	11.3	up to 1	190.1	0.3	51.2
201 to 800	3,758	26.9	6	1,754.7	2.6	77.8
801 to 4,000	5,455	39.0	22	10,324.4	15.0	86.0
4,000 to 10,000	1,788	12.8	74	11,257.9	16.4	85.1
> 10,000	1,397	10.0	381	45,121.9	65.7	84.8
Total	13,980	100.0	58	68,649.0	100.0	84.7

Source: Orplana (2008)

Due to the technological developments achieved both on the agriculture and on industry sides, average production yields have grown from 3,000 litres/ha/year (67 GJ/ha/yr) in early 1980s to 6,500 litres/ha/year (145 GJ/ha/yr) in 2005 (UNICA, 2006). Considering these results, for the production of 15.9 billion litres of ethanol in 2005 it was possible to save almost 2.9 million hectares. Production yields based on conventional process can reach 8,000 litres/ha/year (178 GJ/ha/yr) in about 8 years or even 9,000 litres/(ha/yr) (about 200 GJ/ha/yr), in case ethanol production from hydrolysis of sugarcane bagasse would reach a commercial stage.

Figure 4.6 shows the evolution of sugarcane yields in Brazil, from 1975 to 2008. Due to the best conditions, yields are higher in Centre-South region and are particularly higher in state of São Paulo (e.g., at least 82 t/ha in São Paulo, in 2006, vis-à-vis 74 t/ha for the national average). On average, yields grew more than 3% per year from 1975 to 1985 and 1% per year from 1986 to 2008. Since 1975 yields have grown almost 60% due to the development of new varieties and to the improvement of agricultural practices.



Source: MAPA (2009)

Figure 4.6. Average agricultural yields of sugarcane production in Brazil from 1975 o 2008

4.2 Biodiesel

In 2008 the production of biodiesel worldwide was estimated as about 12 BL. Brazil has covered about 10% of the total world production, and was the fourth (or fifth) largest producer, after Germany (2.2 BL), USA (2.0 BL), France (1.6 BL) and close to Argentina (1.2 BL) (REN21, 2009). In Brazil, the biodiesel production in 2008 was close to 1.2 BL. The production up to June 2009 was estimated as 654.4 ML, about 42% larger than the production during the same six months in 2008.

It is estimated that more than 80% of the biodiesel production has been from soy oil (FAS-USDA, 2008)¹⁷; about 10% from sunflower, 7% from residual oil and fats (Amaral et al., 2008), and only 3-4% based on other raw materials such as castor, palm and babassu). Brazil is worldwide one the largest soybeans producers and its production comes from plantations, mostly located in the Central and in the South regions (47% and 36% of the total production, respectively). The two states with higher production are Mato Grosso (29%), in the Central region, and Paraná (21%), in the South (CONAB, 2008).

PETROBRAS, the stated-controlled oil company, is the main agent acting on biodiesel blends. The company has also been engaged in programs aiming at induce the production of raw materials in poorest regions, development of technology and also the enlargement of the production capacity¹⁸.

The authorized capacity of biodiesel production is estimated as almost 3.7 BL, distributed in 62 industrial units. According to the Brazilian regulatory agency ANP, there are 23 additional plants in the process of being authorized plus a further eight existing plants for increasing production. Table 4.2 shows the production and distribution of the authorized production capacity in Brazil. The bulk of the production capacity (70%) is concentrated in just 15 industrial plants, in eight states. The five top largest biodiesel plants represent 32% of the authorized capacity (the largest plant has a capacity of 274 ML/yr) (ANP, 2009). Also, 24 out of 62 plants have production capacity lower than 12 ML/yr and 36 plants have capacity up to 36 ML/yr. According to ANP (2009), only 3.6% of the installed capacity would allow the production of biodiesel from tallow. Most of the plants can use different vegetable oils.

Table 4.2. Existing capacity of biodiesel production at the end of 2008 and accumulated production from March 2005 to October 2008

Region	Industrial units	Capacity (1000 m ³ /year)	Share of total capacity (%)	Accumulated production (1000 m ³)	Share of accumulated production (%)
North	6	203	5.4	44	3.2
Northeast	8	720	19.2	310	22.3
Central	27	1,381	36.7	551	39.7
Southeast	14	751	20.0	198	14.2
South	7	704	18.7	286	20.6
Total	62	3,760		1,390	

Source: ANP (2009)

The high number of biodiesel plants in the Central region is explained by the concentration of soybean production in that part of the country. For example, Mato Grosso, the main producer region of soybeans, has almost 25% of the authorized capacity. This is followed by the states of Rio Grande do Sul and Sao Paulo. A relatively new comer is the state of Goiás, which has increased production

¹⁷ There is uncertainties regarding this number; the Brazilian government states that the share of soybean oil is close to 70% while critics of the biodiesel program state that the share of soybeans could be as high as 90%. In a survey done in 2008, from all the biodiesel plants in production only 35% responded the requested information on the percentage of raw materials used (Amaral et al, 2008).

¹⁸ The company has three industrial units with total capacity of production of 170 ML of biodiesel per year; in 2008 it was noticed that more ten units could be build up to 2012, with additional capacity of 850 ML.

rapidly in recent years stimulated by good infrastructure and closeness to the market (see Table 4.3). Biodiesel production in São Paulo is explained by the large existing capacity of refining vegetable oils and by the size of the local market. The state of Rio Grande do Sul, with long historical production of soybean, became the most important biodiesel producer of biodiesel in 2008, covering about 30% of the production (CONAB, 2008).

Table 4.3. Biodiesel production (since March 2005) and capacities of biodiesel and vegetable oils production (2008)

State	Biodiesel ¹			Share of soybeans production (%) ²	Vegetable oils (1,000 t/day) ³	
	# of units	Capacity (1000 m ³ /year)	Accumulated production (1000 m ³)		Processing capacity	Refinery capacity
Mato Grosso	22	932	228	28.5	24.8	2.6
RG Sul	4	636	283	13.8	25.8	2.0
São Paulo	8	636	198	2.6	17.8	5.9
Goiás	4	438	323	10.5	19.3	3.5
Bahia	3	307	126	4.2	5.5	1.0
Maranhão	1	130	55	2.0	2.0	---
Piauí	1	97	64	1.3	2.5	0.2
Paraná	3	68	3	20.5	22.6	3.5
Brazil	62	3,760	1,390		155.4	21.6

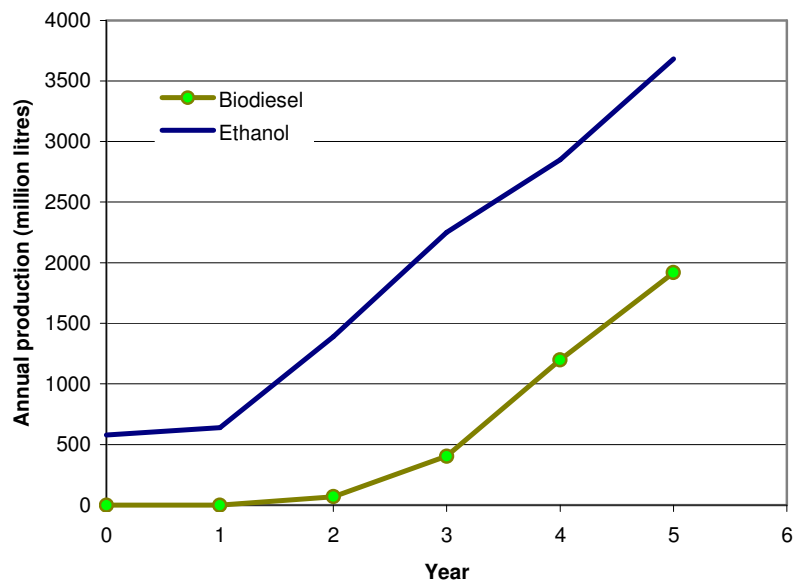
Sources: ¹ ANP (2009)

² CONAB (2008) – estimated production

³ ABIOVE (2008) – installed capacities

According to the National Energy Plan (EPE, 2007), the diesel consumption in 2030, in a business-as-usual scenario (not considering deep changes in the transportation), is estimated as 95.5 billion litres, being 74.8 billion litres in the transport sector. The total consumption that year would reach 97.9 billion litres, taken also into account the consumption for electricity generation and other consumptions in the energy sector. The Energy Plan presents a scenario in which the biodiesel consumption would be equivalent to a B12 blend (12% of biodiesel in the fuel blend, volume basis), that would represent a consumption of 11.7 billion litres; the consumption would be 4,9 billion litres in 2030 in case of B5 blends, in a BAU scenario for the diesel consumption.

Figure 4.7 shows a comparison between ethanol and biodiesel production during the first five years of large-scale production of each program (ethanol, fifth year in 1980, and biodiesel in 2009, with an estimated production of 1,92 BL). Considering the production of biodiesel in 2008 (about 1.2 BL), the production for matching the estimated consumption in 2030 would require a continuous growth at average rates of 10.4% per year along the period; data are presented in Annex A.



Source: MAPA (2009) for ethanol, and ANP (2009) for biodiesel

Figure 4.7. Production of ethanol and biodiesel along the first five years of large-scale production

4.3 Solid biomass

The main sources of solid biofuels come from forestry/wood and sugarcane production. Firewood includes wood used for charcoal production and also field and timber residues. Solid biomass from sugarcane includes bagasse and the so-called trash (top and leaves of the sugarcane plant).

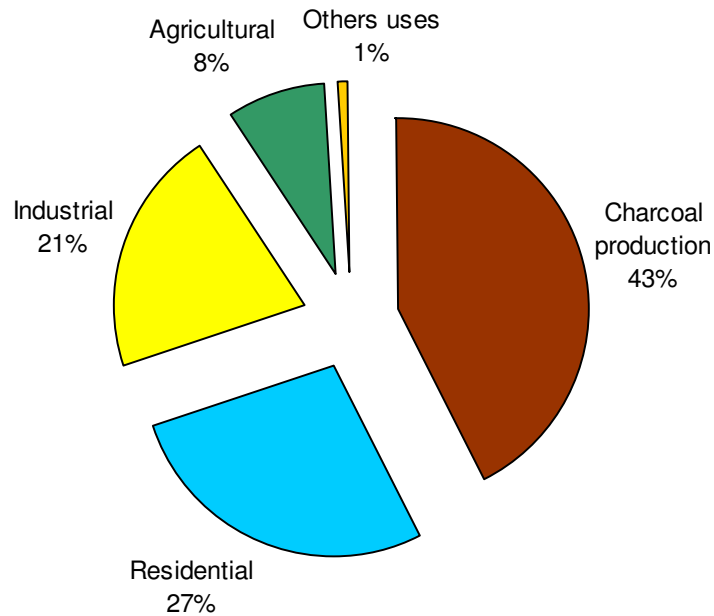
4.3.1 Firewood and residues

In Brazil, the Energy Balance does not allow the identification of the energy consumption due to firewood and forestry/timber residues in different sectors. In 2007, the total energy consumption of wood products was evaluated as 1,198 PJ, with the bulk of it (43%) as charcoal. Residential and industrial sectors are also very important consumer sectors (covering 27% and 21%, respectively, of the total wood energy consumption) (EPE-MME, 2008). Figure 4.8 shows the main consumers of wood by 2007.

The consumption of residues is more relevant in industries, mainly in the pulp and paper sector. Firewood is mainly consumed in the food and beverage and in the ceramic branches. Firewood supply and consumption from 2000 to 2007 is shown in Figure 4.9; data are presented in Annex A.

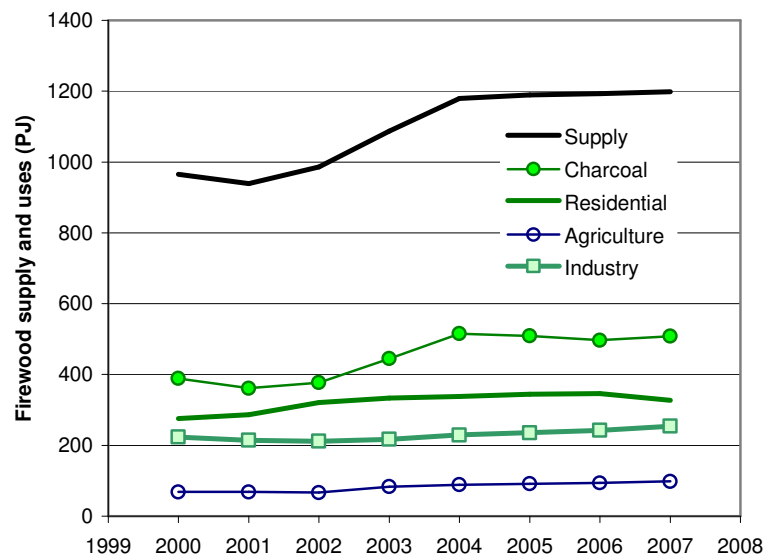
The main use of charcoal has been in the iron and steel industry, where there is certain tradition as substitute of coal coke as chemical reducer (about 75% of the production, from 2000 to 2007). Generally, forests planted for charcoal production are located as close as possible to the steel and iron plants, which provides to this fuel a competitive advantage. Eucalypt plantations in the state of Minas Gerais are an example of this regional supply. Other industrial branches that consume charcoal are other metallurgic and cement industries. The consumption in the residential sector, for

cooking, is also relevant (8-9% of the production from 2000 to 2007), but with a tendency for stabilizing/declining in recent years due to income growth Figure 4.10 shows the evolution of charcoal production and its use in recent years; data are presented in Annex A.



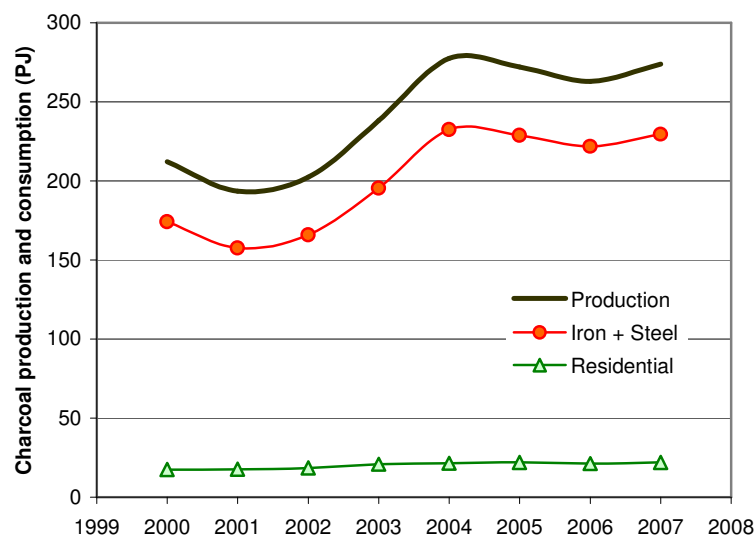
Source: EPE/MME (2008)

Figure 4.8. Wood energy consumption in 2007



Source: EPE/MME (2008)

Figure 4.9. Firewood supply and main uses in Brazil – 2000-2007



Source: EPE/MME (2008)

Figure 4.10. Charcoal production and main consumptions in Brazil – 2000-2007

The energy potential for the main solid biomass sources was estimated by the authors; the firewood estimations were calculated based on the are the following assumptions:

- the annual growth rate of wood supply for the main energy consumption uses (including electricity and charcoal production) was estimated as about 3.9% from 2002 to 2007¹⁹; from the total wood supply figure for energy purposes in 2007 (EPE-MME, 2008) – 1,198 PJ – it was calculated the supplies in 2008, 2010, 2015 and 2020.

Table 3.4 shows the results of the estimates for firewood, forestry/wood residues and sugarcane residues; comments regarding sugarcane residues are presented in the next section.

4.3.2 Sugarcane residues

So far, bagasse is the unique sugarcane residue used as energy source; bagasse derives from the fibres of the sugarcane plant and results from the crushing process for juice extraction. Bagasse is available at the mills site and is used as fuel for raising steam in cogeneration systems. As previously mentioned, from a statistical point of view, despite the fact that most of the sugarcane mills in Brazil produce both sugar and ethanol, the consumption for sugar production is allocated in the industrial sector and the consumption for ethanol production in the energy sector. The evolution of the sugarcane consumption from 2000 to 2007 is presented in Figure 4.11; as can be seen, despite the growth of ethanol production in recent year, the bulk of bagasse consumption is still due to sugar production. Among the non-energy uses of bagasse, the main destination is as forage for animal

¹⁹ See section 4.2: Current and Expected Future Energy Use of Biomass – solid biomass.

livestock. Part of the bagasse not used during the harvest period is also discarded after losing quality when the rain season establishes.

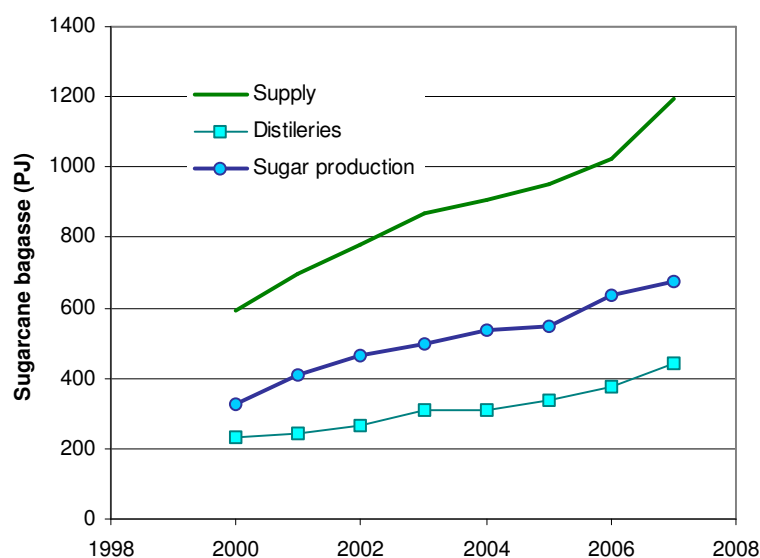
Table 4.4. Potential of gross energy production from the main solid biomass sources in Brazil from 2008 to 2020 (PJ)

Solid biofuels	2008	2010	2015	2020
Firewood (including charcoal production)	1,245	1,343	1,626	1,968
Forestry/wood residues ¹	800	1,000	1,150	1,300
Sugar cane residues (bagasse + top + leaves) ²	1,181	1,345	2,198	3,307
Total	3,226	3,688	4,974	6,575

Notes:

¹ Made on figures presented at the previous Country Report Brazil (2005), applying conversion factors from BEN (2008);

² considering sugarcane production in 2008 (558 Mt) and estimates (635 Mt in 2010, 829 Mt in 2015 and 1,038 Mt in 2020) (Desplechin, 2009); considering maximum availability of 280 kg of bagasse/t of sugarcane (with 50% absolute moisture) and of 165 kg of tops and leaves/t of sugarcane (with 15% absolute moisture); consumption as fuel of all bagasse and 25% of the trash in 2015 and 50% in 2020; LHV of bagasse as 7.56 MJ/kg, with 50% moisture, and LHV of tops and leaves as 12.96 MJ/kg, with 15% moisture (Walter and Ensinas, 2009).



Source: EPE/MME (2008)

Figure 4.11. Sugarcane bagasse – availability and main uses – 2000-2007

The availability of sugarcane residues at the mills site is expected to grow in the years to come due to the phasing out of cane burning before its harvesting; there is an agreement between sugarcane producers and state governments (e.g., in São Paulo, Minas and Goiás) that define 2017 as the deadline for the burning practice. As consequence, all sugarcane will be mechanically harvested and tops

and leaves will be at least partially available to be used as fuel at the mills. It is estimated that at least 50% of the so-called sugarcane trash (leaves + tops) should be left at the field, to protect the plant and the soil.

The estimates presented in Table 4.4 for bagasse and trash are based on the following assumptions:

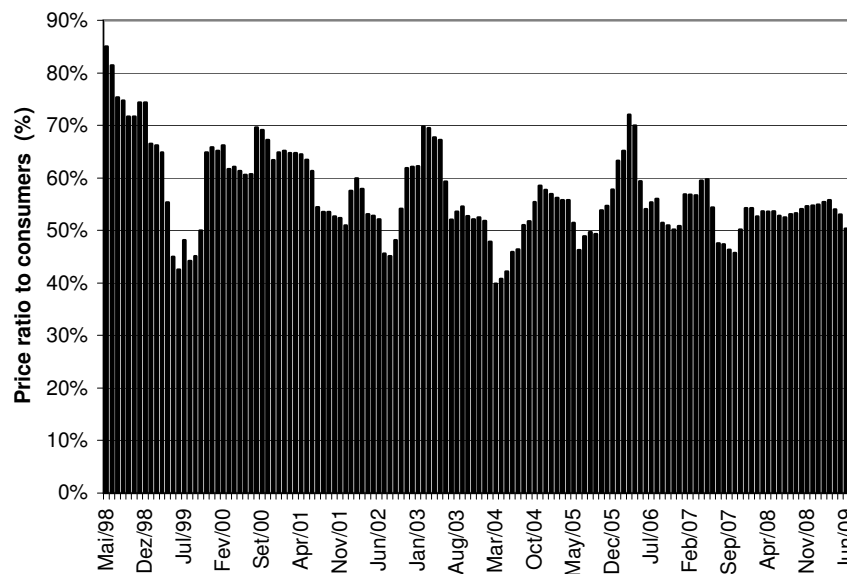
- the sugarcane production in 2008 (558 Mt) and estimates up to 2020;
- fibres content of 14%, on average, that result availability of 280 kg of bagasse/t of sugarcane (with 50% absolute moisture);
- mass of tops and leaves that is equivalent to 140 kg per tonne of sugarcane transported to the mill, and 15% absolute moisture (resulting 165 kg of tops and leaves/t of sugarcane);
- consumption as fuel of all bagasse and 25% of the trash in 2015 and 50% in 2050;
- LHV of bagasse as 7.56 MJ/kg, with 50% moisture, and LHV of tops and leaves as 12.96 MJ/kg, with 15% moisture (Walter and Ensinas, 2009).

As can be seen in Table 4.4, the availability of sugarcane residues is expected to double in the period 2008-2015. In case of the commercial availability of technologies of second-generation biofuels production, part of such residues would be used as raw material; R&D efforts in Brazil have been focused on bagasse conversion rather than on trash, due to its better properties for ethanol production through hydrolysis.

5. Biomass Prices

5.1 Ethanol

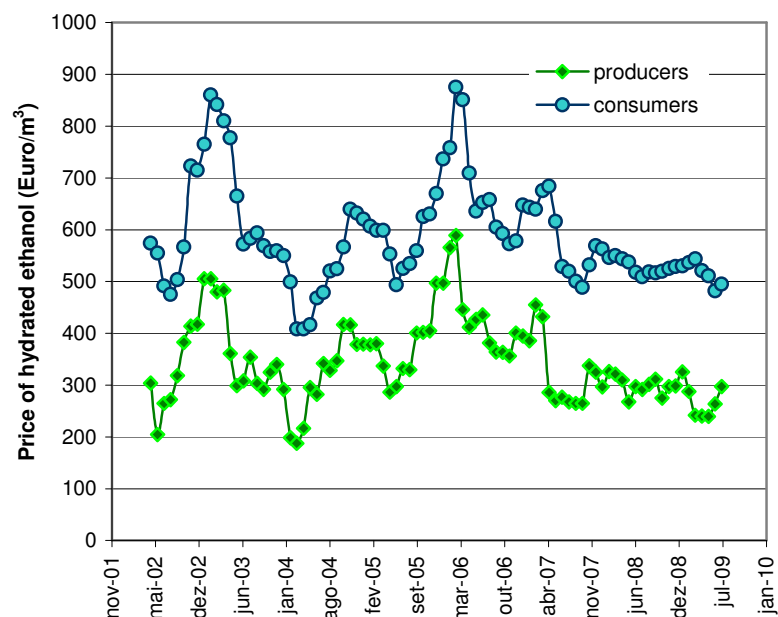
Figure 5.1 shows the evolution of the price ratio to consumers (ethanol/gasoline) in the city of São Paulo, from May 1998 to July 2009. It can be seen that since the full deregulation of fuels (by the end of 1990s) only in few occasions the price ratio has been close to 70% (prices per litre) (e.g., August-September 2000; February-March 2003; March-April 2006). It is important to notice that for most of the flex-fuels models currently available in Brazil, 70% is understood, on average, as the break-even ratio between ethanol and gasoline prices.



Source: Jornal da Tarde (up to 2001) and ANP (2009) (after 2001)

Figure 5.1 Price ratio to consumers (ethanol/gasoline) in the city of São Paulo – March 1998 to July 2009 – current prices per litre

As an illustration, the average price of hydrated ethanol to the consumers in the city of São Paulo in July 2009 was 1.205 R\$/l (0,451 Euro/l) (while the average price of gasoline C, i.e., E25, was 2.340 R\$/l (0.876 Euro/l)). In July 2009, the average price paid to the distributors was 0.951 R\$/l of hydrated (0.356 Euro/l), while the average price paid to producers was 0.728 R\$/l of hydrated (0.273 Euro/l). The differences between prices paid to producers and to distributors, and between prices paid to distributors and by consumers, correspond to freight costs, to taxes and to margins (distributor and sellers). Prices paid to producers and by consumers of hydrated ethanol in São Paulo, from May 2002 to July 2009 are presented in Figure 5.2.



Source: ANP (2009) for prices paid by consumers and CEPEA-USP (2009) for prices paid to producers

Note: Original prices, in R\$/l, were corrected to constant prices by IGP-DI, and then converted to Euro using the exchange rate in July 30th 2009 (1 Euro = 2.4338 R\$).

Figure 5.2 Hydrated ethanol average prices (Euro/m³ – constant prices, July 2009) – paid to producers and paid by consumers – May 2002 to July 2009

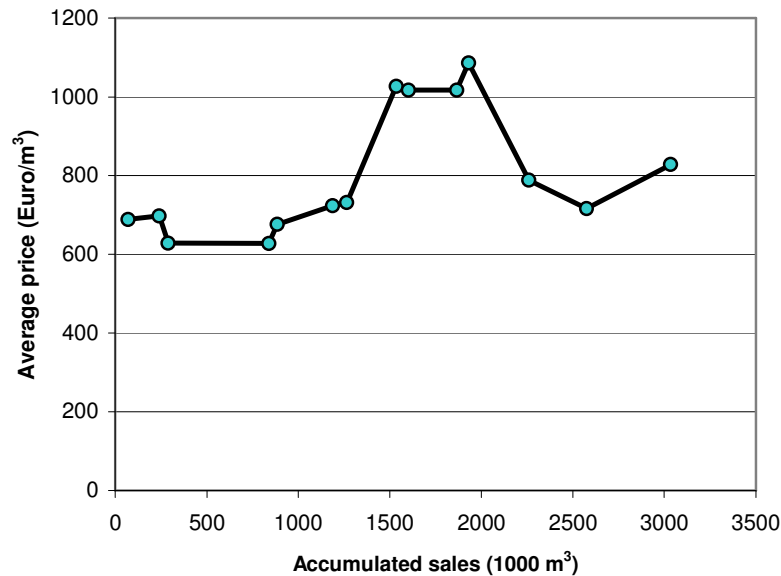
5.2 Biodiesel

Figure 5.3 shows the evolution of the average prices paid in 14 auctions of biodiesel so far carried out in Brazil²⁰. The total volume sold in these auctions is more than 3.0 BL. Average prices reached the top in auctions 7 to 10, from April to August 2008, and since then have dropped due to the reduction of vegetable oil prices in the international market.

The average price paid in last auction was 828 Euro/m³ of biodiesel (by the end of May 2009); at the same time the average price paid to producers of mineral diesel was 519 Euro/m³, that means an over price of about 60%²¹.

²⁰ The auctions are organized by the ANP.

²¹ Supposing the same heating value and that the substitution ratio is 1 litre of biodiesel = 1 litre of mineral diesel.



Source: ANP (2009)

Figure 5.3. Average prices paid to biodiesel producers in Brazil (using the exchange rate at the time of the auction)

5.3 Solid biomass

Average prices to consumers of some solid biomass are presented in this section. Except for metallurgic coal, all prices presented in Table 5.1 are based on EPE-MME (2008); they reflect market conditions and include taxes and transportation costs. Therefore, they may embrace large and small consumers according to the usual market of each energy source. For metallurgic coal prices were from MDIC (2009), adding on them inland transport costs plus internalisation taxes.

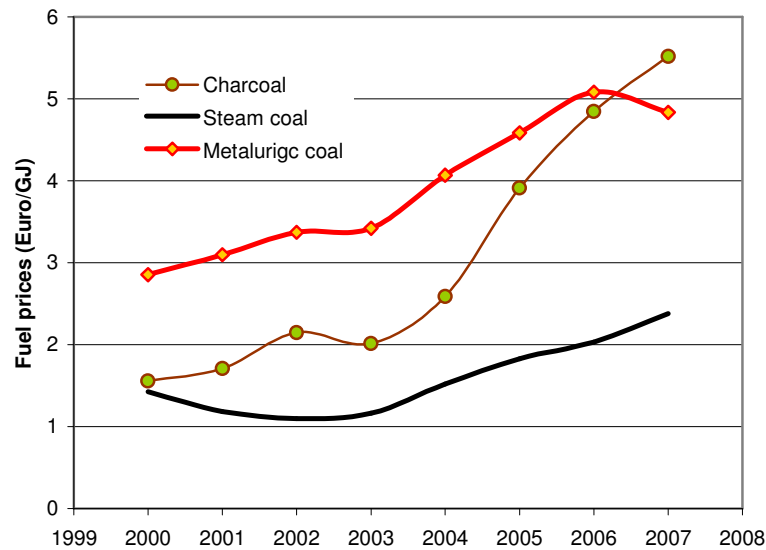
Original prices are published in Brazilian currency and were promptly converted to US dollars according to the exchange rate by the end of each year. The results were converted to 2007 constant dollar using CPI-U index from US. Finally, values in US dollars were converted to Euro using the average exchange rate (parity) found for 2007 (1 Euro = 1.376 US\$).

Table 5.1 Fuel prices in Brazil from 2000 to 2007 (Euro/GJ)

	2000	2001	2002	2003	2004	2005	2006	2007
Charcoal	1.6	1.7	2.1	2.0	2.6	3.9	4.8	5.5
Firewood	1.4	1.3	0.9	1.1	1.3	0.8	1.1	1.1
Steam coal	1.4	1.2	1.1	1.2	1.5	1.8	2.0	2.4
Natural gas	3.8	3.3	3.2	3.2	3.8	5.1	6.6	8.0
Fuel oil	4.7	4.1	3.8	4.8	5.1	6.8	7.8	8.1
LPG	14.9	10.8	11.3	12.9	13.4	15.6	18.2	20.1
Metallurgic coal - imported (a)	2.9	3.1	3.4	3.4	4.1	4.6	5.1	4.8

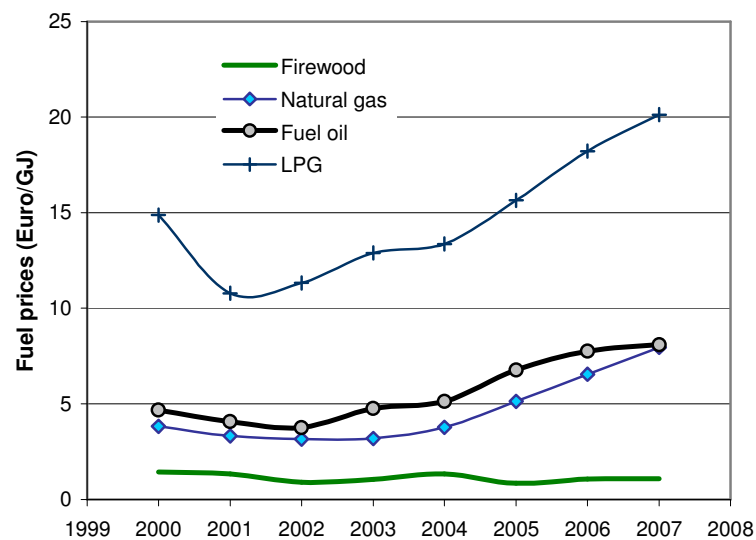
Notes: (a) values from MDIC (2009); FOB prices, adding on them taxes and local transport. Remaining figures are from BEN (2008).

Figure 5.4 and 5.5 shows the evolution of these prices. Figure 5.4 allows the comparison of charcoal prices to steam coal and to metallurgic coal. As previously mentioned, the main market for charcoal in Brazil is in the iron and steel industry. On the other hand, Figure 5.5 allows the comparison of firewood prices to LPG (households use, for cooking) and natural gas and fuel oil (industrial use).



Source: EPE-MME (2008) and MDIC (2009) for metallurgic coal

Figure 5.3. Average fuel prices in Brazil (Euro 2007)



Source: EPE-MME (2008) and MDIC (2009) for metallurgic coal

Figure 5.4. Average fuel prices in Brazil (Euro 2007)

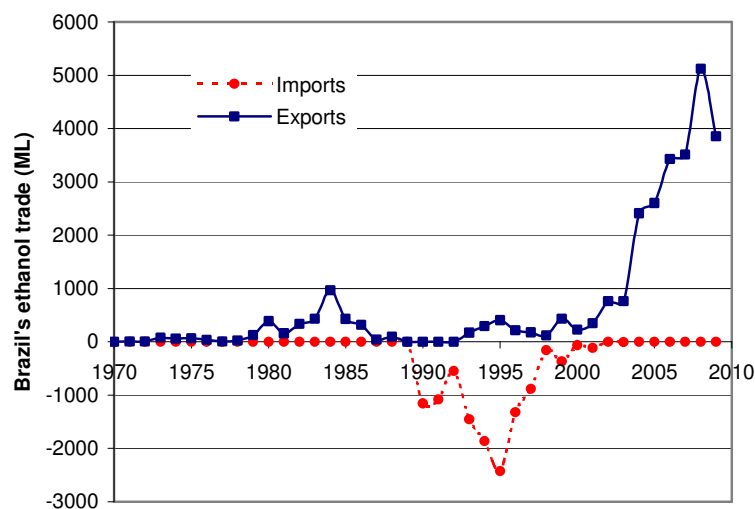
6. Biomass Import and Export

In this Chapter, data of biomass imports and exports are presented. Due to its adequate conditions for biomass production, Brazil is a big potential exporter of biomass. However, what have been remarkable so far are the exports of ethanol, mainly since late 1990s; the production of biodiesel is very recent, and there have been not exports of biodiesel. In what concern solid biomass, there is no significant information of exports of pellets, briquettes or charcoal.

6.1 Ethanol

Large-scale exports of ethanol from Brazil is a relative new event, as can be seen in Figure 6.1. 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 since 2004 exports of fuel ethanol have been much higher than 1 billion litre.

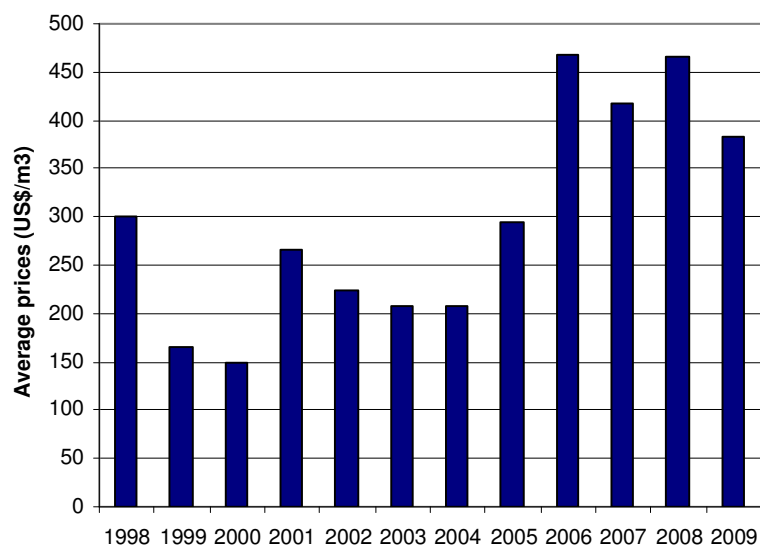
It is estimated that exports will drop in 2009 regarding the previous year; from January to July exports summed-up 1.9 BL, about 75% of the amount exported in 2008 in the same period. The reduction is mostly due to the drop of direct imports to US, explained by the lower consumption of automotive fuels, the lower price of gasoline and by few contracts signed in the second half of 2008, due to price uncertainties.



Sources: EPE-MME (2008) and MAPA (2009)

Figure 6.1. Exports of ethanol from 1970 to 2008 (estimates for 2009)

Figure 6.2 shows the average prices (FOB) received by exporters of ethanol from 1998 to 2009 (in case of 2009, average prices from January to July). Data regarding exports and prices are presented in Annex A.



Sources: MAPA (2009)

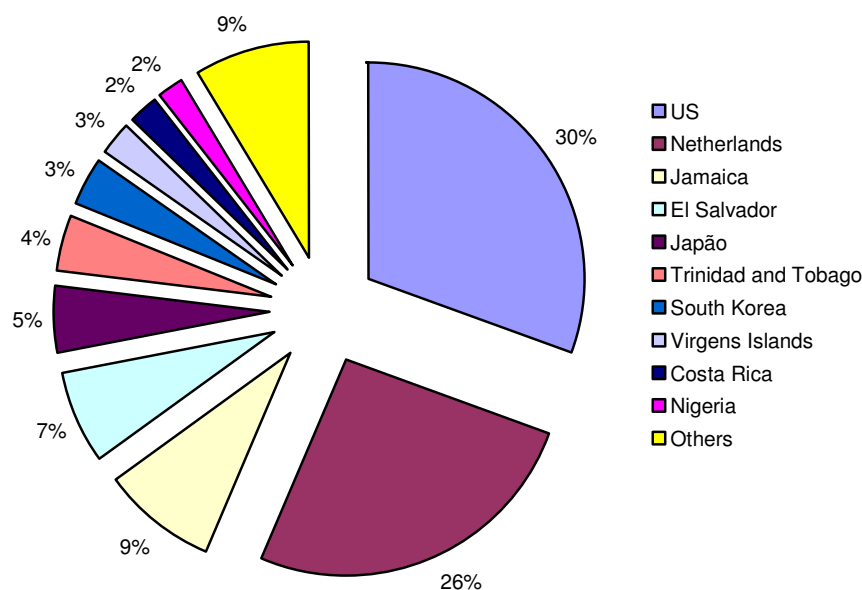
Figure 6.2. Average FOB prices of ethanol exported (for 2009 average prices up to July)

The bulk of ethanol exporters are to United States, straight to there or through Central America and Caribbean Countries, in order to take advantage of an agreement known as CBI – Caribbean Basin Initiative. Up to 7% of the US ethanol demand may be imported duty-free under the Caribbean Basin Initiative (CBI), even if the production itself occurs in another country (UNCTAD, 2006). When price volatility is higher, exports through Caribbean (and Central America) countries are risky due to the transit delay (Recharge, 2009).

Figure 6.3 shows the main importers of Brazilian ethanol in 2008; the data basis is not consolidated and corresponds to 4.85 BL traded, while the total amount exported was 5.12 BL (i.e., almost 95% of the total volume). About 1.5 BL were directly imported by United States (30% of the total volume accounted), while more 1.2 BL (25%) should have reached US through Jamaica, El Salvador, Trinidad and Tobago, Virgin Islands, Costa Rica and other countries²². In 2008, The Netherlands, Japan and South Korea were also important markets for the Brazilian ethanol.

The bulk of the ethanol exported has been shipped in the port of Santos, in state of São Paulo; the figures for 2007 and 2008 were close to 70%, while in 2009 more than 77% has been exported from up to July.

²² UNICA (2009) states that the exporters to CBI countries in 2008 reached 1,316.3 million litres.



Sources: MAPA (2009)

Figure 6.3. Main importers of ethanol in 2008 (not consolidated information)

6.2 Solid biomass

According to EPE-MME (2008), Brazil exported few tonnes of charcoal (irregular flows) along the period 1993-2007 (e.g., 5,000 t in 1997 and 28,000 t in 2004). In fact, since 1993 Brazil has mostly imported (probably high quality) than exported charcoal (almost 3 times more; accumulated imports of 445 thousand tonnes vis-à-vis accumulated imports of 156 thousand tonnes from 1993 to 2007); however, exports have represented very few regarding final energy consumption (about 0.4% along the period).

Regarding briquettes and pellets, it has been impossible to precisely estimate the amount of their exports due to the accuracy of trade statistics from the forestry sector: the NCM – Marcos Harmonic System – Code number 44.01.3000 embraces sawdust, wood chips, wood waste and scrap, and there is no specific information for briquettes and pellets. The great majority of these exports is as wood chips for pulp and paper production abroad. Therefore, all these wood by-products, hide the biomass exported and imported for energy purpose unless charcoal (NCM 44.02) and firewood (NCM 44.01.1000) because they receive individual codes (Braziltradenet, 2009).

7. Barriers and Opportunities for International Trade

7.1 Ethanol

Brazil is an important player in the international trade of ethanol: is worldwide the second largest producer, has been for many years the largest exporter, has the lowest cost of production, and is, in short to mid-term, the only country that can significantly enlarge its production (with some difficulties) aiming at supply the international market.

On the other hand, the production of biodiesel in Brazil is a new event, and all efforts are currently concentrated on assuring the supply of the growing domestic market. Thus, in short to mid-term there is no real perspective that Brazil could be an exporter of biodiesel. The hypothesis of being an importer is also not effective, as in case of drawbacks with the domestic production the easiest alternative would be slowing down biodiesel introduction in the market.

In this sense, this section exclusively is devoted for the barriers and opportunities for enlarging Brazilian share in ethanol international trade.

7.1.1 Perspectives

It has been previously presented that exports of ethanol in 2008 reached 5.1 BL, representing about 18% of the total national production, and covering almost 8% of the world consumption (estimated as 67 BL, according to REN21 (2009))²³. So far, the reduction on exports in 2009 seems to be caused by the decrease of direct importers from United States²⁴.

UNICA (2008) predicts that the amount of ethanol exported should reach 15.7 BL in 2020 (the domestic consumption would be 49.6 BL in the same year), while EPE-MME (2008) presents figures almost equal (50.8 BL for the domestic market and 15.8 BL for exports). In some sense these figures are rather conservative, as a study has shown that it would be possible to produce – only for exporting – more than 100 BL in 2025 (Cerqueira Leite et al., 2009).

7.1.2 Duty-tax barriers²⁵

For many years Brazil has blamed against duty-tax barriers imposed by United States and European Union; in short-term, these are the main important barriers for the enlarging of ethanol trade. US impose most-favoured nations (MFNs) import duties of 142.7US\$/m³ plus a 2.5% ad valorem (according to value) tariff on ethanol. MFN basically means normal trade rules, with no special advantage and no special constraint. In many cases, this tariff offsets lower production costs and imposes a significant barrier to imports. An argument seldom presented in US is that these tariffs ensure that the benefits of the domestic US ethanol tax credit do not accrue to foreign producers (United States International Trade Commission, 2004).

²³ Considering the consumption outside Brazil – about 47 GL – Brazilian exporters covered almost 11% of the market in other countries.

²⁴ In fact, more information and further analysis is required in order to understand the whole picture. Exporters of sugar have raised in comparison to the same period of 2008, due to production constraints in India, and this issue should be taken into account.

²⁵ This section is based on Walter et al. (2008).

US gives special treatment under the CBI agreement but the amount traded under this regime has been far below the 7% cap (e.g., about 3% in 2005). However, the situation may change as new investment is going into ethanol plants in Caribbean (Zarilli, 2006).

Duty-free treatment of ethanol in US has raised some concerns. Some experts believe that trade liberalization would induce modernization of the US industry and could act as safeguard against supply disruptions. Nonetheless, an attempt to get rid to the MFN import duties on ethanol in 2006 failed due to strong opposition from the Midwest senators (FO Lichts, 2006). In addition, the numerous state-level subsidies provide so many incentives to domestic production that barriers to imports would remain even if the import tariffs were to be removed (Zarilli, 2006).

Also under MFN regime, European Union imposes a duty of 192 Euro/m³ on undenatured alcohol (102 Euro/m³ in case of denatured alcohol); e.g., all imports from Brazil are under MFN rules. Reduced duty and duty-free regimes operate under preferential trade arrangements between EU and developing countries. Many countries of Africa, South and Central America and Asia are included in these preferential trade arrangements that aim at drug diversion, sustainable development and good governance (Zarilli, 2006).

Part of the difficulties of biofuels trade liberalization has roots in agricultural policies and the need to protect farmers. Ethanol is internationally classified as an agricultural product, but biodiesel is classified as industrial (Zarilli, 2006). There is no perspective of any change on US and EU policies regarding duty-tax in short term.

7.1.3 Logistics

Most of ethanol exported has been shipped in the port of Santos, located in the state of São Paulo (relatively close to many ethanol distilleries), but with serious constraints regarding shipment capacity. In fact, only two terminals in Brazil can operate with vessels like Suezmax and VLCC²⁶, both terminals operated by PETROBRAS (Ilha D'Água, in state of Rio de Janeiro, and São Sebastião, in state of São Paulo). So far, this has not been a serious constraint, but certainly could be in the future.

Other logistic constrain is the distance between mills/distilleries and the ports. Transportation of ethanol by trucks at large distances doesn't make sense from economic, energetic and environmental points of view. Ethanol producers and TRANSPETRO – the logistic subsidiary of PETROBRAS – are investing in pipelines, e.g., (i) an investment of US\$ 1.7 billion that would allow the shipment of ethanol in Paranaguá (state of Paraná), (ii) a pipeline of 1,000 km that would allow the flow of ethanol from the largest producer region in state of São Paulo to Santos (US\$ 1 billion would be invested); (iii) a pipeline 1,120 km long that would allow the flow of more than 6 BL from state of Mato Grosso to an oil refinery in state of São Paulo (about US\$ 600 million would be invested). TRANSPETRO estimates that logistics costs could represent 20% of the total cost of exporting ethanol, and that this cost could be reduced at least 50% with an optimised infrastructure (Lepsch, 2007).

In addition, TRANSPETRO plans to expand by 2015 its capacity of ethanol exports up to 13 billion litres, from 2 billion litres in early 2009. This includes diversifying transport modals (e.g., by

²⁶ Respectively, with transportation capacities of 150 thousand m³ and 280 thousand m³.

pipelines, by railways and boats), enlarging ducts' and terminals' capacity and having more high-capacity vessels available (Agencia Brasil, 2009).

7.1.4. Environmental issues²⁷

Due to social sector pressure, sustainability criteria have been proposed in order to promote the effective sustainable production of biofuels. Theoretically, such criteria will differentiate between products with similar fuel properties, but with important differences in their supply chain. The adoption of sustainability criteria could result in certification of biofuels production. However, there are also concerns that a certification process could impose new barriers for the international trade in biofuels.

Brazil will continue to be a key producer in the global ethanol market over the coming years, as local conditions for ethanol production are comparatively favourable taking into account factors such as land availability and climate, long-term experience, existing commercial technology (the so-called "first generation"), and the size of the domestic market. Nevertheless, if the sustainability of Brazilian ethanol production was more widely recognised, these comparative advantages could be reinforced.

It is internationally recognised that Brazilian ethanol is produced at the lowest cost and its feasibility does not depend on subsidies. However, environmental and social aspects still need to be properly addressed, as there are knowledge constraints and controversy about many crucial issues.

Most of the ethanol production in Brazil can be considered sustainable, taking into account the current standards defined by the Directives of European Union. Does not taken into account greenhouse (GHG) emissions due to land used change (LUC) (both considering direct and indirect impacts), reduction of greenhouse gas emissions vis-à-vis the life cycle of gasoline would be at least 70%. Energy and GHG balances could be improved in the years to come and, in this sense, process diversification, phasing-out of sugarcane burning, trash recovery and its use as fuel or raw material, and trash deposition in the field, will be essential.

Regarding direct impacts of land use change, the main conclusion is that the growth of croplands, and more specifically the growth of sugarcane areas, has mainly occurred in lands previously occupied with pastures. Other conclusion is that the growth of sugarcane areas did not induce the displacement of cattle herds to other regions of Brazil, as have been frequently questioned. Along the period 1996-2006, almost 90% of the enlargement of sugarcane areas was concentrated in four states (São Paulo, Minas, Paraná e Goiás) and in all those states there was significant phasing-out of pasturelands, besides growth of forested areas.

It is difficult to evaluate indirect impacts on land use change, in particular regarding the recent growth of sugarcane. However, there are clear evidences that deforested areas in Amazon and in Cerrado have been used mostly for pasturelands and in a lower extent to soybean production. On the other hand, there is no evidence that the growth of sugarcane in São Paulo has caused deforestation in Centre-West and in North of Brazil.

Regarding socio-economic aspects of sugarcane production, in a recent report by Walter et al. (2008), a regional and more detailed approach was adopted based on welfare indicators (e.g. health

²⁷ This section is based on Walter et al. (2008b). For more information, see also Smeets et al. (2008).

and education) and on indicators of wealth and wealth distribution. The analysis was carried out comparing municipalities of the same size, with and without sugarcane activity (cropping and industrial conversion to ethanol). The results indicate that in most cases the municipalities in which sugarcane production is present have better parameters than those where it is absent.

Other environmental impacts of the sugarcane sector, such as water consumption, contamination of soils and water shields due to the use of fertilizers and chemicals, and loss of biodiversity, are less important in comparison to other crops. This can be explained by the following: in Brazil sugarcane production mostly occurs without irrigation; the development of sugarcane varieties has occurred over decades (with resulting higher yields and resistance to diseases and plagues); the use of biological control techniques; the use of biological fixers of nitrogen and of residues of production allowing a partial or total reduction of conventional fertilization; and the use of best agricultural practices (e.g. the reduction of erosion). However, due to the concentration of sugarcane production in some regions and the size of many factories, monitoring all the above-mentioned aspects is essential, besides dissemination and wide adoption of best practices (as has already occurred in some producer regions).

7.2 Solid biofuels

Regularly, only wood chips have been exported for Japan and US, in general for pulp and paper production; trade normally occurs among branches of the same holdings. Some constraints for exporting of solid biomass are listed below.

Supply oscillations – During 2004 and 2005, a combination of attractive prices and biomass surplus in the state of Amapá, brought the opportunity for exporting part of this biomass for energy purpose (Omachi et al, 2004). Nowadays, there is enough demand from the pulp and paper industry with attractive prices and long-term contracts.

Local demand for biomass residues – In the Brazilian south there is already a market for biomass residues from wood industries, reducing the feasibility of pellets production for exporting.

Currency ratio – Recently, an exporting barrier was the fluctuation of currency exchange rate. Also, the devaluation of US currency vis-à-vis Brazilian Real (that has started in 2004) reduced the earning of local exporters.

Non-certified wood production – As presented on Chapter 3, there is significant production in the North region of Brazil, but it is mostly based on extrativism. As this wood production is not certified, it would be not possible to produce and export briquettes and pellets with residues of this production.

Logistics – Currently, this is the main barrier for exporting solid biomass. Most of planted forests are located at places where 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 cases. It is known some attempts of pellets production for exporting that failed due to the high transportation costs. Considering the high availability of wood residues in state of Paraná (but rather dispersed in some cities), Serrano (2009) showed that it is not feasible to transport residues for more than 200 km to the pelletization units located at the Paranaguá port.

Fluvial transport may be a solution for the Northern and Centre-Western region due the existence of several rivers appropriated for this purpose. For the North-Eastern and South-Eastern regions,

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 connections are made by trucks.

Densifying biomass through pellet and briquettes production may be an alternative to reduce costs of transportation for some cases, but it depends on an appropriate cost-benefit analysis. However many sites do not show competitiveness even with such transformations (Dolzan & Walter, 2006).

Considering different site with biomass availability, Dolzan and Walter (2006) found overall logistic costs ranging from 65% to 90% vis-à-vis the wood chips production cost. Looking at differences between the existing transportation costs and those ones from the ideal logistic composition scenario, the authors found values from 1.69 Euro/GJ to 3.27 Euro/GJ added inappropriate logistic confirming the importance of removing such barriers.

Regarding ports, despite the highly privileged Brazilian condition in terms of places for structuring them, most of the existing ones are public and their services are both expensive (outstanding tariffs) and inefficient (despite some exceptions). In addition, the ports are not equipped for fast carrying of bulk biomass such as charcoal, bagasse, wood pellets or chips which both have low aggregated value. In order to solve this problem, private ports located at strategic places and conveniently equipped with belt-carriers have been used for wood chips exports. At least three big companies for both energy and pulp purposes have well structured and specialized ports such as Amcel, in Santana – state of Amapá, in the North, and Bianchini (Tanac), in state of Rio Grande, in the South. Companies like these have presented highly competitive prices at outstanding levels if ordinary freights and port taxes are taken into account. 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.

8. Concluding Remarks

Brazil has long tradition on biomass production and consumption and has either potential to enlarge biomass share in its energy matrix and to be a big player in the bioenergy international trade arena.

For more than 30 years ethanol has been used in large scale, displacing gasoline. Since the launch of flex-fuel vehicles, and due to its large market success, ethanol has a consolidated position in the transportation sector, and the tendency is to enlarge its participation in the years to come. Regarding exports, the perspectives are also positive, but the extent of the international trade, and of Brazil's participation in it, will depend on a set of factors, including trade policies in the most important consumer markets (United States and European Union), on policies regarding mitigation of GHG emissions, on the success of the RD&D efforts on second generation biofuels, etc. The estimates present in this report regarding exports of ethanol from Brazil are rather conservative, and reflect the point of view of producers in mid-term.

Brazilian experience with biodiesel is new, but even though the results achieved in less than five years are remarkable. However, the rationale of the biodiesel program tends to be contested in short to mid-term, as the production has been mostly based on soy oil, and financial support has been given to soy producers and large companies that dominate the soy supply chain. More important, the expansion of soy cropping has been blamed for deforestation in some parts of the country. Anyhow, at least B5 blends will be used in Brazil in very short-term, and in a conservative scenario the growth on production will be consequence of enlarging diesel demand. There is no perspective for exporting biodiesel in short-term.

Regarding solid biomass, there is either potential for enlarging the consumption in the domestic market and for exporting. The best perspectives in the domestic market are on charcoal use, enlarging its use in steel and iron industries. However, before that it will be necessary to assure that charcoal production is sustainable. There is also potential for pellets production, both for the domestic and for the external markets, but as there is no tradition on pellets production and consumption, this is the very first barrier to be overcome.

Specifically regarding trading, there are two challenges for Brazil. The first drawback to be addressed is regarding logistics constraints, which impacts the feasibility of solid biomass (e.g., pellets) and ethanol exporting. Logistic constraints have been addressed by producers and traders in case of ethanol, e.g., with investments on pipelines and on maritime terminals.

The second challenge for exporting is improving sustainability on biomass (and biofuels) production. Along the years there is a growing perception that rather be a barrier for trading, sustainability can be a comparative advantage. There are initiatives both concerned to forest products and to ethanol, and at least a significant share of the production fulfils the existing criteria in more constrained markets. However, there is still a lot to do in this regard, despite the results so far achieved.

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Annex

Table A.1. Total energy supply – Brazil, 2000-2007 (PJ)

Energy sources	2000	2001	2002	2003	2004	2005	2006	2007
Natural gas	298	346	421	456	510	561	602	649
Coal	119	116	126	138	150	147	146	157
Wood	571	574	606	637	660	675	687	683
Bagasse	560	656	733	810	849	885	1014	1120
Other primary renewables	126	128	140	162	168	178	194	208
Coquefication gas	52	51	49	53	56	56	54	58
Coque	272	265	279	280	285	269	257	281
Electricity	1194	1115	1168	1232	1296	1351	1404	1484
Charcoal	202	185	193	227	266	262	255	262
Ethanol	270	253	275	262	291	307	292	375
Other secondary	9	9	8	9	9	8	8	9
Oil products	3527	3513	3461	3358	3464	3504	3581	3740
Diesel	1235	1282	1320	1293	1367	1356	1374	1459
Fuel oil	398	355	345	302	273	275	257	272
Gasoline	558	546	522	551	570	571	607	601
Liquefied petroleum gas	328	324	310	293	301	298	301	311
Naphtha	339	331	276	300	300	305	306	326
Kerosene	136	142	136	96	102	109	101	110
Other secondary from oil	343	369	364	364	377	401	410	454

Source: EPE/MME (2008)

Table A.2. Final energy consumption by sectors – Brazil, 2000-2007 (PJ)

Sectors	2000	2001	2002	2003	2004	2005	2006	2007
Residential	866	844	866	875	894	914	925	933
Industry	2.563	2.576	2.737	2.863	3.024	3.077	3.214	3.430
Transport	1.984	2.001	2.058	2.016	2.155	2.196	2.230	2.413
Energy sector	538	568	603	663	688	739	788	881
Others	650	653	667	685	701	723	738	777
Total	6.601	6.642	6.931	7.102	7.462	7.649	7.896	8.433

Source: EPE/MME (2008)

Table A.3. Energy consumption in industry – Brazil, 2000-2007 (PJ)

	2000	2001	2002	2003	2004	2005	2006	2007
Natural gas	162	191	234	245	279	302	317	339
Coal	391	380	406	418	436	416	403	438
Oil products	579	543	524	493	468	485	484	539
Electricity	528	502	549	579	620	631	660	694
Biomass	860	919	984	1085	1176	1198	1307	1375
Others	42	40	40	42	46	44	43	46

Source: EPE/MME (2008)

Table A.4. Energy consumption in transport – Brazil, 2000-2007 (PJ)

	2000	2001	2002	2003	2004	2005	2006	2007
Gasoline	555	544	520	549	568	569	605	598
Ethanol	244	225	255	243	270	292	268	361
Diesel Oil	1009	1040	1082	1049	1123	1117	1135	1203
Others	176	192	202	176	195	218	223	251

Source: EPE/MME (2008)

Table A.5. Firewood supply and consumption – Brazil, 2000-2007 (PJ)

	2000	2001	2002	2003	2004	2005	2006	2007
Production	966	940	986	1,087	1,180	1,190	1,193	1,198
Charcoal	389	361	378	445	515	510	497	508
Residential	275	287	321	333	338	345	347	327
Agriculture	69	69	67	83	89	91	94	99
Industrial	224	215	212	217	229	236	243	254

Table A.6. Charcoal production and consumption – Brazil, 2000-2007 (PJ)

	2000	2001	2002	2003	2004	2005	2006	2007
Production	212	193	202	238	277	272	263	274
Imports	0	0	0	1	1	2	4	0
Exports	0	0	0	0	1	0	0	0
Iron + Steel	174	158	166	195	232	229	222	229
Residential	17	18	19	21	21	22	21	22

Table A.7. Ethanol and biodiesel production in Brazil, in the early years of each program

Year	Ethanol	Biodiesel	Production (million litres)		Growth rates regarding previous year (%)	
			Biodiesel	Ethanol	Biodiesel	Ethanol
0	1975	2004	0	580		
1	1976	2005	1	640		10
2	1977	2006	69	1,390	9,273	117
3	1978	2007	403	2,250	484	62
4	1979	2008	1,200	2,850	198	27
5	1989	2009	1,920	3,680	60	29

Source: MAPA (2009) for ethanol, and ANP (2009) for biodiesel

Table A.8. Wood production (except for charcoal and firewood) based on planted forests and extrativism (Mm³)

	Planted forests		Extrativism
	Timber and logs	Pulp and paper	
1990	14.1	33.0	97.5
1991	13.9	35.8	46.2
1992	13.6	38.6	53.1
1993	15.5	41.7	62.8
1994	18.0	51.4	62.5
1995	19.6	48.6	61.6
1996	49.3	33.8	49.9
1997	21.7	35.4	26.3
1998	33.9	38.6	22.1
1999	23.4	41.1	21.3
2000	25.7	46.0	21.9
2001	28.8	41.0	20.1
2002	31.7	43.4	21.4
2003	50.2	49.5	20.7
2004	41.2	46.3	19.1
2005	45.9	54.7	17.4
2006	45.7	55.1	18.0
2007	44.2	61.0	16.4

Table A.9. Exports of ethanol from 1998 to 2008 (estimates for 2009) and average FOB prices paid

	Volume exported (1,000 m ³)	Average FOB prices (US\$/m ³)
1998	118	301
1999	432	166
2000	227	149
2001	346	267
2002	759	223
2003	762	209
2004	2,408	207
2005	2,601	294
2006	3,429	468
2007	3,512	418
2008	5,124	466
2009	3,854	383