IEA Bioenergy

Country Report

Brazil

IEA Bioenergy Task 40

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Summary

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Abstract

Worldwide, few countries in a reasonable to large development stage have an energy matrix with an important share of renewable energy sources like Brazil has: in 2013, 46.4% of its primary domestic energy supply was covered by renewables, being the share of biomass sources estimated as about 28.6% of the total energy consumption (almost 3,100 PJ). Historically (despite recent drawbacks), the most remarkable biomass experience is due to fuel ethanol production/consumption in large-scale, reaching the production of 26.3 billion litres in 2013 (22.9 BL consumed in Brazil and 2.9 BL exported). In 2005, Brazil started a biodiesel program and since 2010 B5 blends (5% of biodiesel in fuel blends, volume basis) are mandatory countrywide; in 2013, biodiesel consumption was more than 3.0 BL. Concerning ethanol, Brazil has been an important player in the international trade scenario, despite recent drawbacks of its production (since 2009). On the other hand, regarding biodiesel Brazil has reached in few years a position among the top world producers, but barely will be in an exporter. There are also constraints as regard solid biofuels (such pellets) and, despite some plans, the existing potential will be barely developed in short-term. The lack of adequate logistics is one the main barrier for trading biomass in large scale, even in case of ethanol. In addition, 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 – and this is also true regarding forest products – could be already considered sustainable.

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Introduction

This is the fourth 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 published in 2005.

Since 2005, Brazil experienced consolidated large-scale biodiesel production and is currently the third largest producer country: the production in 2013 surpassed 3.0 billion litres (BL), and that year only Germany and US produced more than Brazil. On the other hand, the domestic consumption of fuel ethanol, that raised continuously since the launch of flex-fuel vehicles in March 2003, and surpassed 26 BL in 2010, declined in 2011-2012; Brazil is worldwide the second largest producer and has also the second largest internal consumer market, in both cases just after United States.

Regarding solid biomass, the consumption of firewood and charcoal has been almost constant in recent years. The consumption of pellets is still small; that some big projects were announced in 2010 and 2011, but the investors gave up.

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

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

Chapter 5 is devoted to assess 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 Annexes.

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[2] (it surpassed 200 million people in 2013); is the largest Portuguese spoken country. Is located in South America and occupies almost 50% of the region; Brazil has boarders with all South American countries, except Chile and Ecuador.

Figure 1.1 presents a South America maps and details of Brazil's topography. It is worth to note that in 2012, according to the World Bank (Trading Economics, 2013), 61.6% of the country's land area was still covered by forests[3] (almost 5,200 km^2, i.e., the second largest area in the world, just after Russian Federation).

Source: Wikipedia (2009)

Figure 1.1 Brazil in South America and its topography

[2] The four largest countries are Russia, Canada, China and United States; larger populated countries are China, India, United States and Indonesia.

[3] Defined as land area under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agriculture production systems (Trading Economics, 2011).

According to the last official demographic survey, in 2010 the Brazilian population reached 190.7 million inhabitants (IBGE, 2011) (203 million is the estimate for December 2014). The average population growth between 2000 and 2010 was estimated as 1.17% per year, and has declined[4]. 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.

Table 1.1 Demographic information – Brazil, 2010

Region	Population (1,000)	Area (1,000 km^2)	Density (hab/km^2)
North	15,830.8	3,851.6	4.1
Northeast	53,023.7	1,556.0	34.1
Southeast	80,353.7	927.3	86.7
South	27,465.5	575.3	47.7
Centre-West	14,114.2	1,604.9	8.8
Total	190,732,7	8,514.9	22.4

Source: IBGE (2011)

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 (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 was in 2013, according to the International Monetary Fund, in the seventh position among the richest countries in the world (see Table 1.2) (IMF, 2014). In 2013 the Brazilian GDP was estimated at 2,246 billion US$. Also according the

[4] It has been predicted that keeping the recent tendency of population growing rates, Brazilian population in 2020 will be stable or even start to be reduced (IBGE, 2010).

IMF, in the same year the Brazilian GDP based on Purchasing-Power Parity (PPP) was 3,013 billion US$. In 2013 the GDP per capita was estimated at 11,172 US$/habitant[5][6].

Table 1.2 Gross Domestic Product of the main seven countries in 2010 and in 2013, in US$ billion (current prices)

Country	GDP 2010	Position 2010	GDP 2013	Position 2013
US	14,527	1	16,768	1
China	5,878	2	9,469	2
Japan	5,459	3	4,899	3
Germany	3,286	4	3,636	4
France	2,563	5	2,807	5
UK	2,250	6	2,523	6
Brazil	2,090	7	2,246	7

Source: IMF (2014)

A big issue in Brazil is income inequality (Gini Index 0.527 in 2012[7]) (World Bank, 2014) that has slowly declined due to income support programs (e.g., 0.606 in 1990, 0.592 in 1995, and 0.539 in 2009). The Human Development Index in 2012 was estimated at 0.730, with a continuous trend of improvement since 1980 (e.g., 0.549 in 1980, 0.6 in 1990 and 0.665 in 2000) (UNDP, 2013).

By 2009, 69% of the total GDP was due to the Services Sector, being the contribution of industries estimated as about 25% (being manufacturing 16%) and of agriculture about 6%. In 2009, total exports represented about 11% of the GDP, while total imports were slightly lower (The Economist, 2012).

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 1.3 presents the main figures regarding foreign trade in 2013; exports reached 242.2 billion US$ and imports were 239.6 billion US$.

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[5] It is worth noting that Brazil in 2009 was not ranked among the 60 countries with the highest GDP per head (both in absolute terms and based on power purchase power) (The Economist, 2011).

[6] About 50% higher than China, and more than 6-7 times higher than India. However, the Brazilian GDP per capita in 2013 was almost 4 times lower than the Japanese and almost 5 times lower than in US (IMF, 2014).

[7] The lower its value, the more equally household income is distributed. In 2009, Brazil has worldwide the tenth highest Gini coefficient.

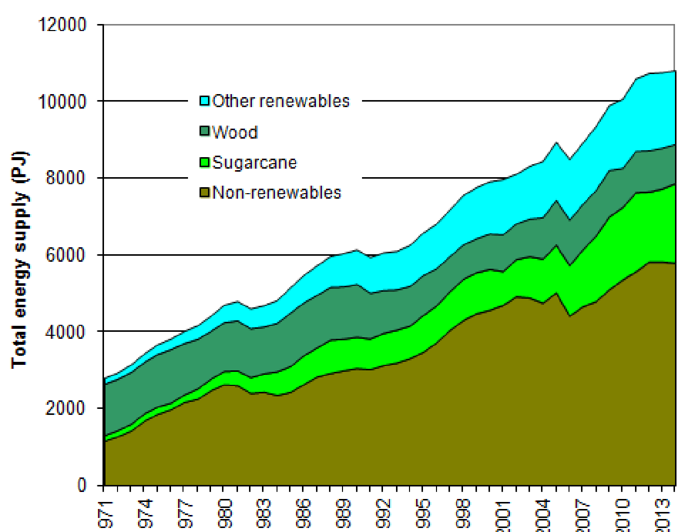
Table 1.3 Foreign trade figures (% of total for the leading markets and leading suppliers)

Main exported products and its share	Main imported products and its share
Ores – 14.5%	Oil and fuels – 19.1%
Transport materials – 13.0%	Mechanic equipment – 14.9%
Soybeans and products – 12.8%	Electric and electronic equipment – 11.8%
Oil and fuel – 9.2%	Vehicles and parts – 9.4%
Meats– 6.7%	Chemicals – 5.5%
Chemicals – 6.0%	Fertilizers – 3.7%
Sugar and ethanol – 5.7%	Plastics – 3.7%
Metallurgic products – 5.5%	Iron, steel and its products – 3.3%
Machines and equipment – 3.7%	Pharmaceuticals – 3.1%
Pulp and paper – 3.0%	Optical and precision equipment – 3.0%
Major countries for the exports and its shares	**Main supplier countries and its shares**
China – 19.0%	China – 15.6%
United States – 10.3%	United States – 15.1%
Argentina – 8.1%	Argentina – 6.9%
The Netherlands – 7.2%	Germany – 6.3%
Japan – 3.3%	Nigeria – 4.0%

Source: MDIC (2013)

1.2 Energy

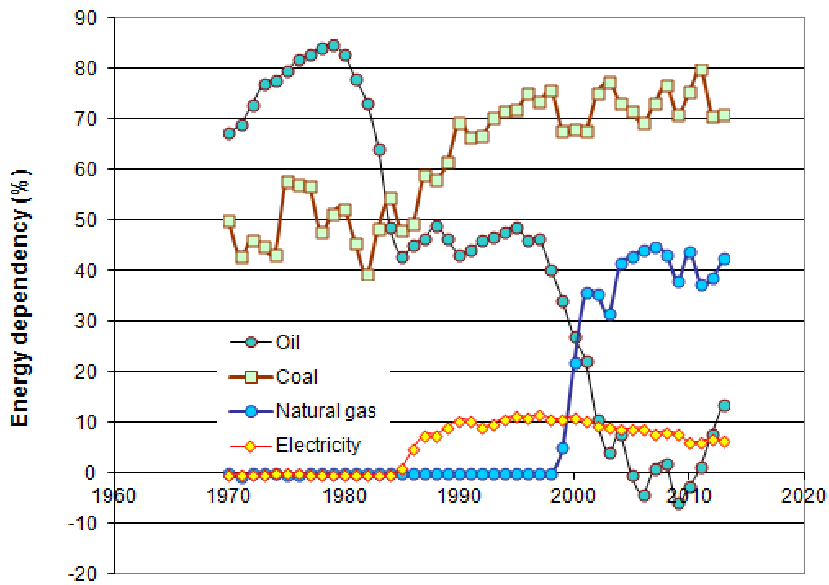
Few countries with reasonable to good level of industrialization, like Brazil, have an energy matrix with such high share of renewable energy sources. In 2013, 46.4% of its primary domestic energy supply was covered by renewables. The share of hydraulic energy that year was 13.0% of the total supply. In the same year, the set of biomass sources covered 28.6% of the domestic energy supply, with a share of 19.1% due to sugarcane products (ethanol and bagasse). Figure 1.3 shows the evolution of the total energy supply in Brazil in the period 1970-2013, and highlights the share of renewables.



Source: EPE/MME (2013)

Figure 1.3 Evolution of total energy supply in Brazil – 1970-2013

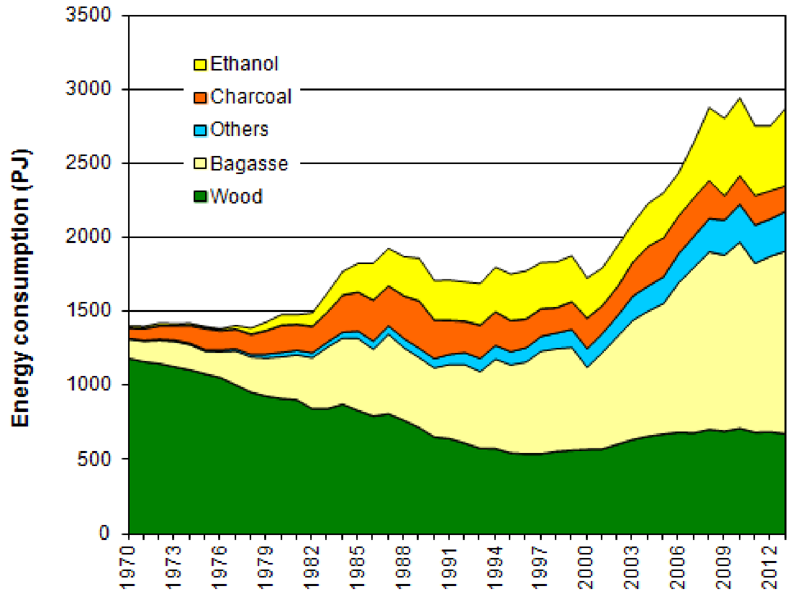
Since the 1980s Brazil has remarkably reduced its dependency on oil supply and since recently (on average) has been self-sufficient (the results on 2012 and 2013 indicate the difficulties for enlarging domestic oil production). On contrary, Brazil is highly dependent on high-quality coal (and coal coke), used for iron and steel production; this dependency was reduced in the early 1980s, when Brazilian government implemented policies aiming at substituting 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 (through 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 it owns half of Itaipu's capacity (the 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 (2014)

Figure 1.4 Evolution of energy dependence in Brazil – 1970-2013

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; in this case, bagasse is used with moderate efficiency for raising steam in boilers and this is the main reason for its high share – the availability is high and the opportunities for other uses are limited so far. In Figure 1.5, "Others" correspond to different agricultural and industrial residues, such as black liquor. It can also be seen that due to the drawbacks of ethanol production the biomass consumption has been almost stable.

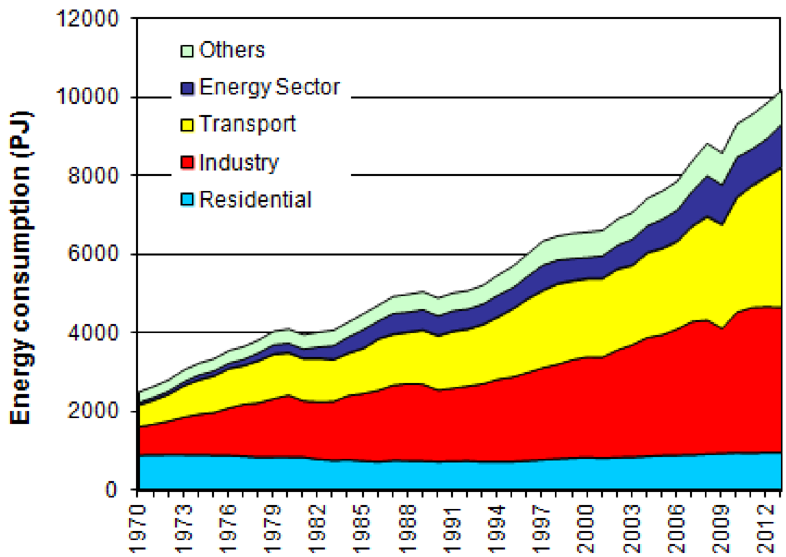


Source: EPE/MME (2014)

Figure 1.5 Final energy consumption of biomass sources – 1970-2013

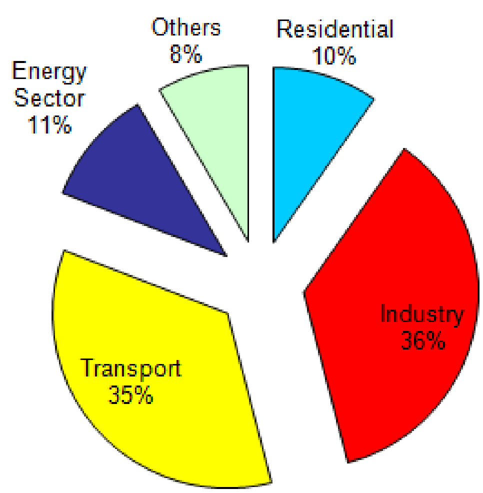
Wood consumption as such is relevant in the residential (775 PJ – 35% of total consumption) and in the industrial sectors (48%). The energy consumption of charcoal is mostly due to the industrial sector (88%), and more specifically in the metallurgic industry.

Considering socio-economic sectors, the industrial is still the one with highest consumption (about 3.7 EJ by 2013; 36.2% of the total), followed by the transport sector (about 3.6 EJ and 34.9% of the total by 2013). 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 2013. Figure 1.7 shows the distribution of final energy consumption within socio-economic sectors by 2013.



Source: EPE/MME (2014)

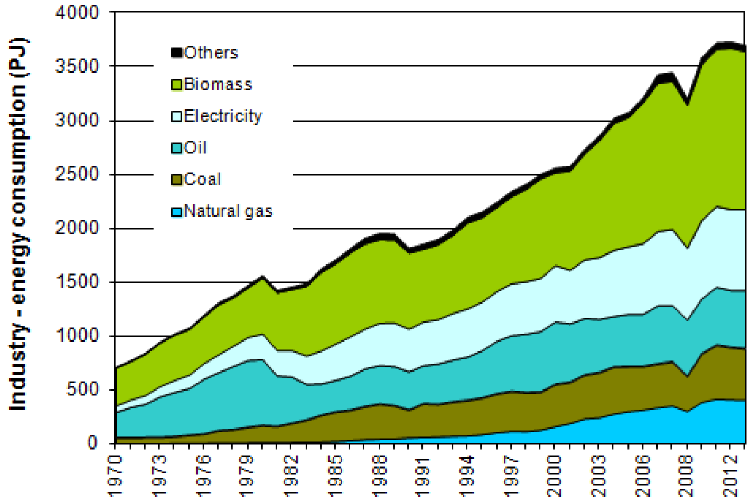
Figure 1.6 Energy consumption by sectors – 1970-2013



Source: EPE/MME (2014)

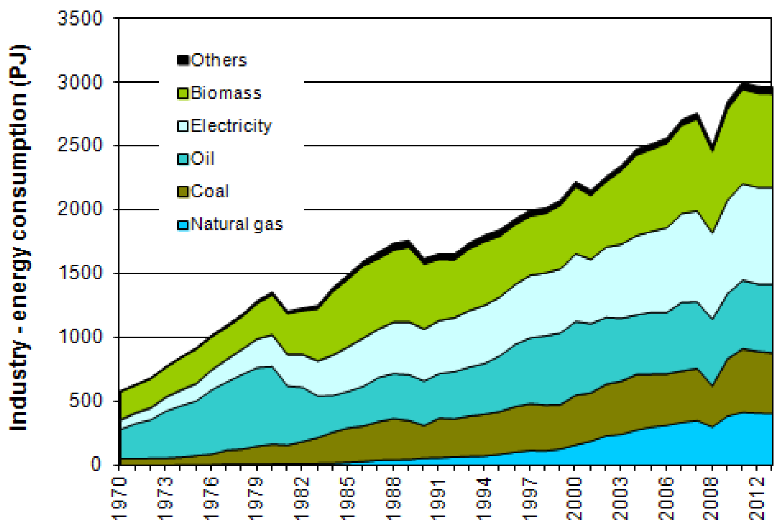
Figure 1.7 Energy consumption by sectors in 2013

The evolution of the final energy consumption within the industrial sector is shown in Figure 1.8 and in Figure 1.9. The difference between these two figures is the inclusion (or not) 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 was 722 PJ in 2013.



Source: EPE/MME (2014)

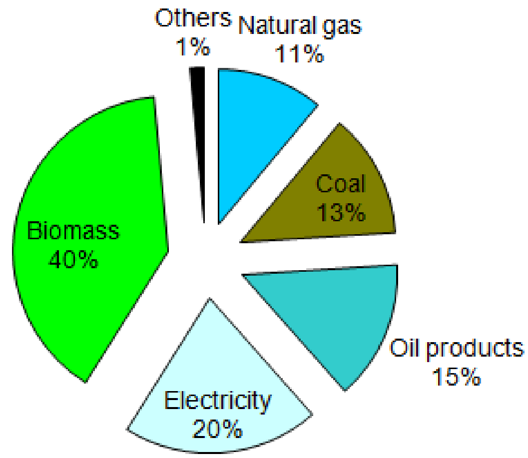
Figure 1.8 Energy consumption in the industrial sector, including bagasse consumed for sugar production



Source: EPE/MME (2014)

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

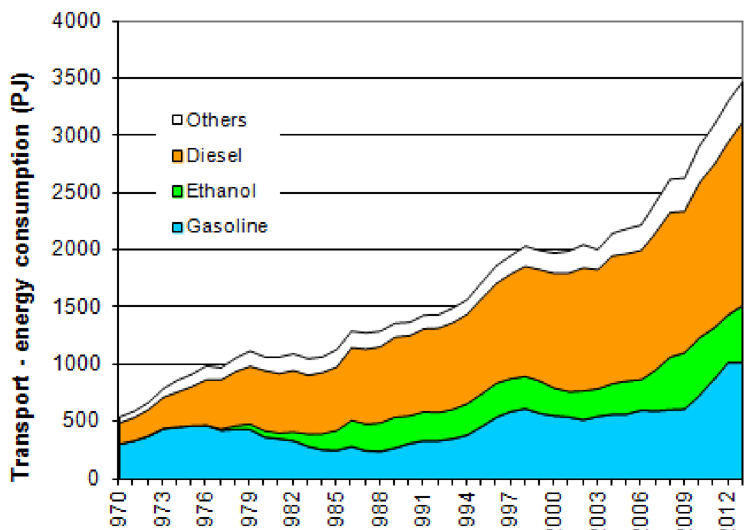
Figure 1.10 shows the structure of final energy consumption in the industrial sector by 2013. The share of biomass would be reduced to 20% in case bagasse consumption is not considered. Details of the energy consumption in the industrial sector from 2003 to 2013 are presented in Annex A.



Source: EPE/MME (2014)

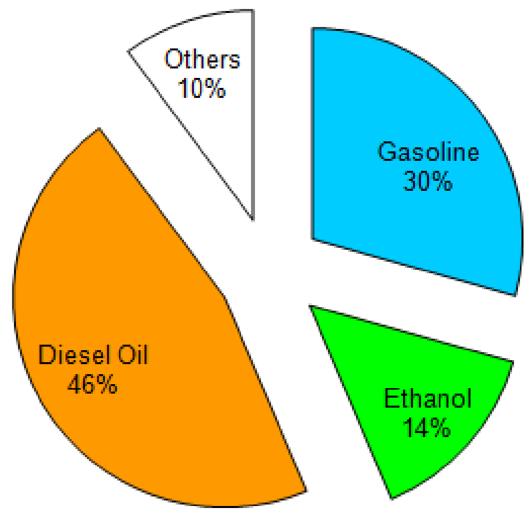
Figure 1.10 Final energy consumption in the industrial sector by 2013

For the transport sector, the evolution of the final energy consumption is shown in Figure 1.11. The growth of ethanol consumption (hydrated ethanol and anhydrous ethanol (that is blended with gasoline) is remarkable since 1976. By 2010, ethanol consumption represented 14% of the energy consumption in road transportation and 31% of the energy consumption of spark-ignition vehicles (49% of the gasoline consumption in energy basis). In Figure 1.11, "Others" correspond mostly to kerosene (consumed in jet engines), biodiesel (consumed blended with mineral diesel) and natural gas (consumed in spark-ignition engines). Figure 1.12 shows the distribution of the energy consumption in the transport sector by 2013.



Source: EPE/MME (2014)

Figure 1.11 Energy consumption in the transport sector – Brazil, 1970-2013



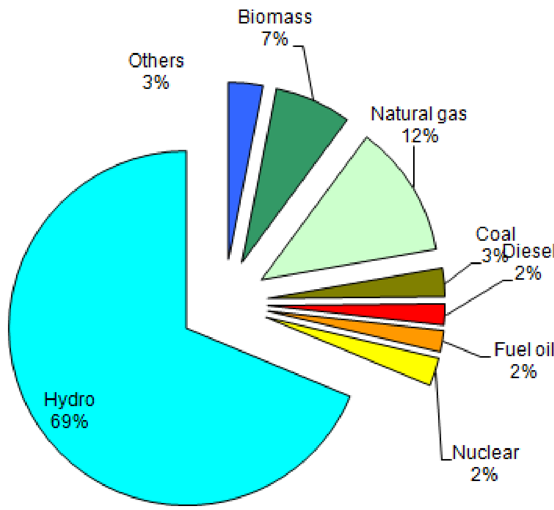
Source: EPE/MME (2014)

Figure 1.12 Final energy consumption in road transport sector by 2013

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 (more than 110 GW over 260 GW). It will be difficult to take full advantage of the remaining potential in the North region as, firstly, there is growing resistance to new large hydro power plants due to the potential environmental and social impacts in the Amazon area and, secondly, because the distance from the largest consumer markets (in Southeast and South regions). For reducing environmental and social impacts the tendency is construction of hydro power plants with small capacity of water storage, for reducing flooded areas.

Figure 1.13 shows the profile of electricity generation in 2013, when 69% of the generation was based on hydro power plants (79% in 2010; a sequence of dry years explain the reduction). 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 569 TWh in 2013, while imports (mostly from Itaipu) summed-up 36 TWh in the same year.

Regarding the installed capacity of electricity production, by the end of 2014 hydro power plants corresponded to more than 70% of the total (also excluding 50% of the Itaipu's capacity). About 10% of the installed capacity is based on thermal power units that burn biomass. Table 1.4 shows the current profile of the installed capacity of electricity production and Table 1.5 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 (2014)

Figure 1.13 Profile of electricity generation by 2013

Table 1.4 Profile of the installed capacity of electricity generation by December 2014

	Capacity (MW)	Share (%)	Number of plants
Hydro – large-scale	87,309	62.97	201
Hydro – small-scale	5,030	3.76	954
Thermal- conventional	39,334	28.20	1,885
Nuclear	1,990	1.49	2
Wind	4,854	3.76	224
Solar	19	0.01	289
Total	138,536		3,555

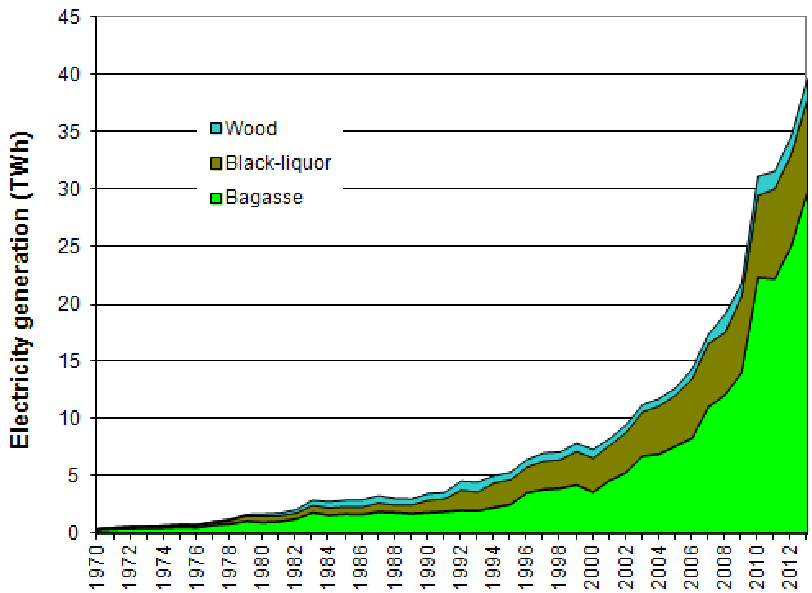
Source: ANEEL (2014)

Table 1.5 Profile of thermal power plants based on biomass by December 2014

	Capacity (MW)	Share (%)	Number of power plants
Sugarcane residues	10,543	79.8	387
Black liquor	1,984	15.0	17
Wood residues	359	2.7	46
Biogas	73	0.6	25
Rice residues	38	0.3	10
Blast furnace gas (charcoal)	51	0.4	7
Vegetable oil	14	0.1	3
Elephant grass	32	0.2	1
Total	13,279		529

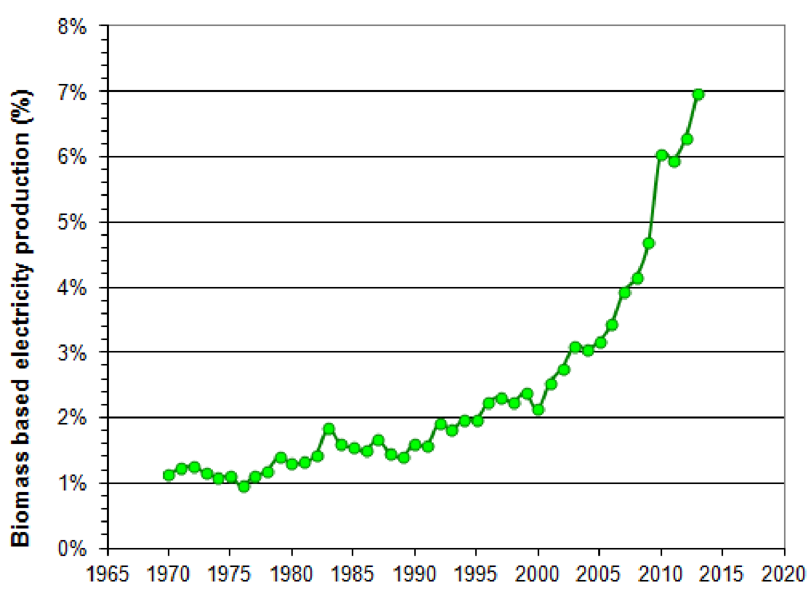
Source: ANEEL (2014)

Figure 1.14 shows the growth of electricity production (since 1970) from the most important biomass sources. In recent years, more than 50% of the electricity produced from sugarcane bagasse (on average, considering total production) has been commercialised with the grid. Figure 1.15 shows the growth of the contribution of electricity production from biomass since 1970.



Source: EPE/MME (2014)

Figure 1.14 Electricity production from biomass – 1970-2013



Source: EPE/MME (2014)

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

1.3 Greenhouse gas (GHG) emissions

Brazil is not an Annex I country in the Kyoto Protocol and, thus, does not have commitments regarding emission reductions up to 2020. However, Brazil is one of the top emitters, even not considering the emissions due to land use change and deforestation that, in the past, was the main reason for high emission levels. Deforestation has drastically been reduced since 2004.

An estimate of emissions per country is presented in Table 1.6. The figures are for 2011, considering and not considering emissions due land use change, deforestation and aforestation (LULUCF[8]); in both cases Brazil is in the sixth position (about 3.1% of total emissions worldwide); about 30% of the total emissions are related to the energy supply chains.. On the other hand, considering historical GHG emissions from 1990 to 2011, Brazilian emissions are estimated at about 40.5 $GtCO_{2eq}$, or 4.8% of total GHG emissions in this period.

The facts that call attention regarding these figures are: (1) the deep reduction of total GHG emissions in about one decade, from 2,322 $MtCO_{2eq}$ (WRI/CAIT, 2008) to 1,419 $MtCO_{2eq;}$ the rapid growth of the emissions due to energy use and agricultural activities, as Brazil was in 18[th] position in 2006 as long LULUCF were not considered (UNDP, 2009); (3) the significant contribution on total GHG emissions in the period 1990-2011.

Table 1.6 GHG emissions per country, in 2011, and accumulated total emissions from 1990 to 2011 ($MtCO_{2eq}$)

Excluding emissions due to LUC and deforestation		Including emissions due to LUC and deforestation		Accumulated total emissions from 1990 to 2011	
Country	Emissions	Country	Emissions	Country	Emissions
World	43,816.73	World	45,913.50	World	840,511.53
China	10,552.61	China	10,260.32	United States	136,751.47
United States	6,550.10	United States	6,135.03	China	122,928.68
India	2,486.17	India	2,358.04	Russian Fed.	52,352.67
Russian Fed.	2,374.31	Russian Fed.	2,216.59	Brazil	40,489.09
Japan	1.307.41	Indonesia	2,052.91	Indonesia	34,235.71
Brazil	1,131.10	Brazil	1,419.10	India	34,096,06
Germany	882.93	Japan	1,170.28	Japan	26,290.91
Indonesia	834,58	Canada	847.08	Germany	20,816.67
Canada	716.21	Germany	805.97	Canada	17,208.30
Iran	715.53	Mexico	723.19	United Kingdom	14,421.16

Source: WRI/CAT (2014)

[8] GHG emissions due to land use, land use change and forestry.

Worldwide, it is estimated that Brazil has the largest stock of carbon in forests (49,335 MtC), 1.5 time 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 two official inventories of its GHG emissions, for the periods 1990-1994 and 2000-2005. According to these studies, the emissions due to land use change and deforestation in Brazil covered 55% and 61% of the total emissions in 1994 and 2005, respectively (1,329 $MtCO_2$ in 2005). In 2005, emissions due to the agriculture were 18.9%, while emissions due to energy production and use contribute with 15%. The balance was due to the emissions in industry (3.6%) and due to waste disposal (1.9%) (Brasil, 2010).

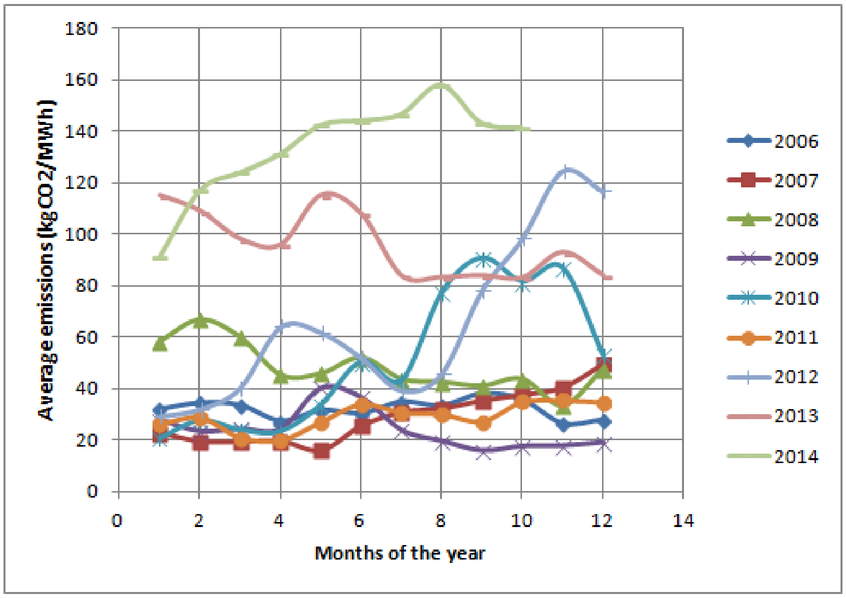
However, due to the drastically decrease on deforestation since 2004 and to the growth of agriculture and livestock, on one hand, and to the more intense use of fossil fuels, the profile of GHG emissions has changed. An estimate for 2010 by the authors of this report, based on tendencies, show that the emissions due to agriculture (including livestock) represent about 30% of the total, while the emissions of the energy supply chains represent 28%; the LULUCF emissions represent about 33% of the total. The total emissions were estimated at 1,476 $MtCO_2$, that is a quite good result compared to the figures presented in Table 1.6.

An official estimate of GHG emissions in 2013 indicate 1,568 $MtCO_2$ as the total figure, being 34.6% due to LULUCF, 30.2% due to the energy production and use and 26.6% due to agriculture and livestock (SEEG, 2014).

Emissions of CO_2 per capita due to energy consumption were 2.22 tonnes/habitant in 2012 (1.4 t/habitant in 1990 and 1.74 in 2009), while the figure for carbon intensity of economic growth was 0.32 $ktCO_2$/million US$ PPP (2005) in 2012 (0.22 $ktCO_2$/million US$ PPP (2000) in 1990 and 0.20 $ktCO_2$/million US$ PPP (2000) in 2009) (IEA, 2014). These figures are still very low compared to other countries (developed and developing countries).

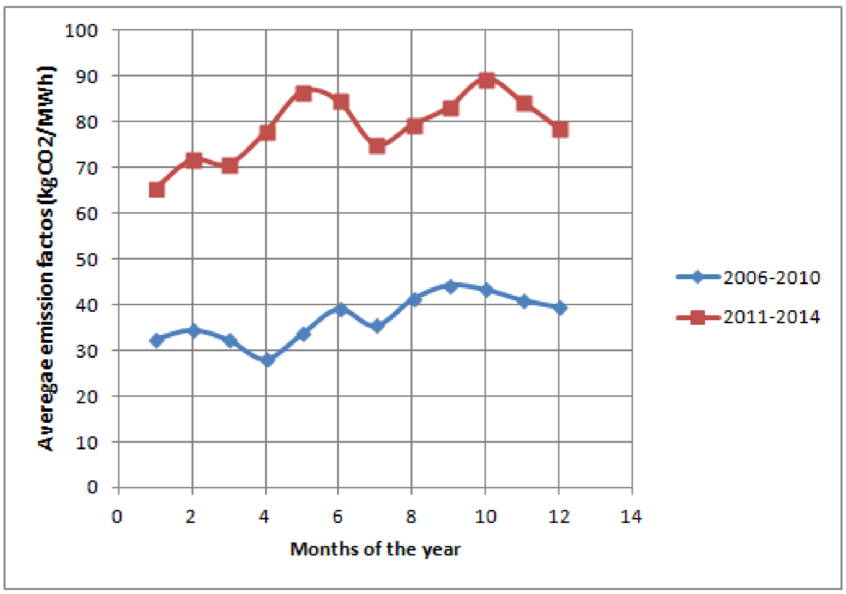
The average CO_2 emission factors due to electricity generation in Brazil (considering the national electric interconnected system) from January 2006 to October 2014 are presented in Figure 1.16. The results are based only on fuel consumption and on the hypothesis that hydro power plants do not cause GHG emissions. The variations along the year are due to seasonal behaviour of electricity production by hydro power plants, as thermal power plants are mostly complementary in Brazil.

Compared to other countries, and due to the profile of electricity generation in Brazil, the estimated CO_2 emissions are quite low. However, observing Figures 1.17 and 1.18 it is it is clear the growing tendency as long as hydro power plants have operated with constrains in recent years (for reducing the risk of deficits and due to the droughts in 2013-2014).



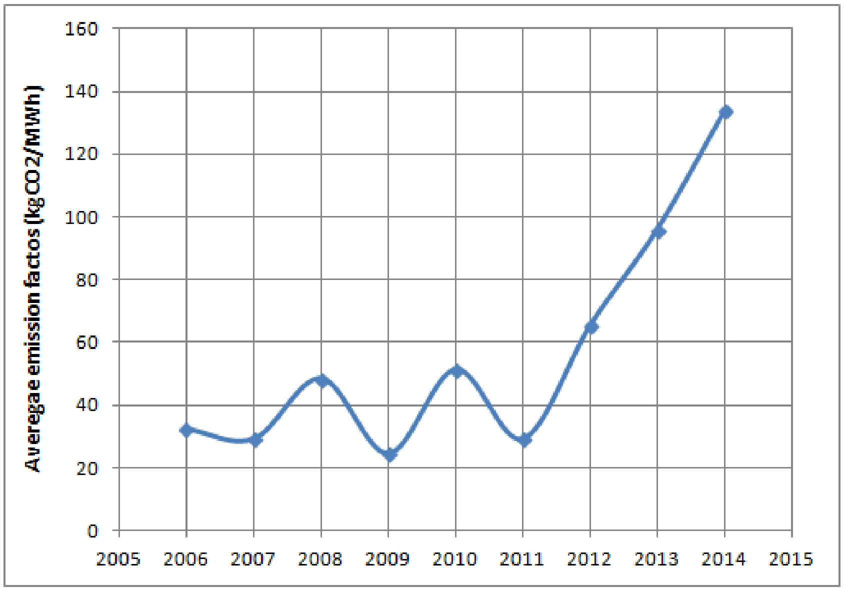
Source: MCT (2014)

Figure 1.16 CO_2 emission factors in the Brazilian electric interconnected system



Source: MCT (2014)

Figure 1.17 Average CO_2 emission factors in the Brazilian electric interconnected system, in two periods



Source: MCT (2014)

Figure 1.18 Average annual CO_2 emission factors in the Brazilian electric interconnected system

2. Energy Policies

2.1 Ethanol[9]

The so-called chicken and egg problem is classic for alternative fuel vehicles: who will buy these vehicles as long as a fuelling infrastructure is not in place, and who will build the infrastructure while 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 a new 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 (due to mandates – see below – and strict regulation by the government) and prices were controlled – both to sugarcane and to ethanol. In fact, the 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, during the 1970s and 1980s the government has obliged the state-controlled oil company (PETROBRAS) to provide and to operate the required infrastructure for transporting, storing, blending and distributing. Eventual losses during ethanol commercialisation were also assumed by PETROBRAS.

In parallel, in order to induce the consumption, the government negotiated with the automobile industry[10] to introduce the required modifications in engines and parts. As large is the share of ethanol in the fuel blend, more modifications are required[11] (Coelho et al., 2006). Already 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%. Along 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 as consequence of 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 (since mid 2014 the range is defined as 18-27.5%), depending on the conditions of ethanol market. Since then 20% was the lowest level reached. In practice, this relative wide range allows to shift the 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%.

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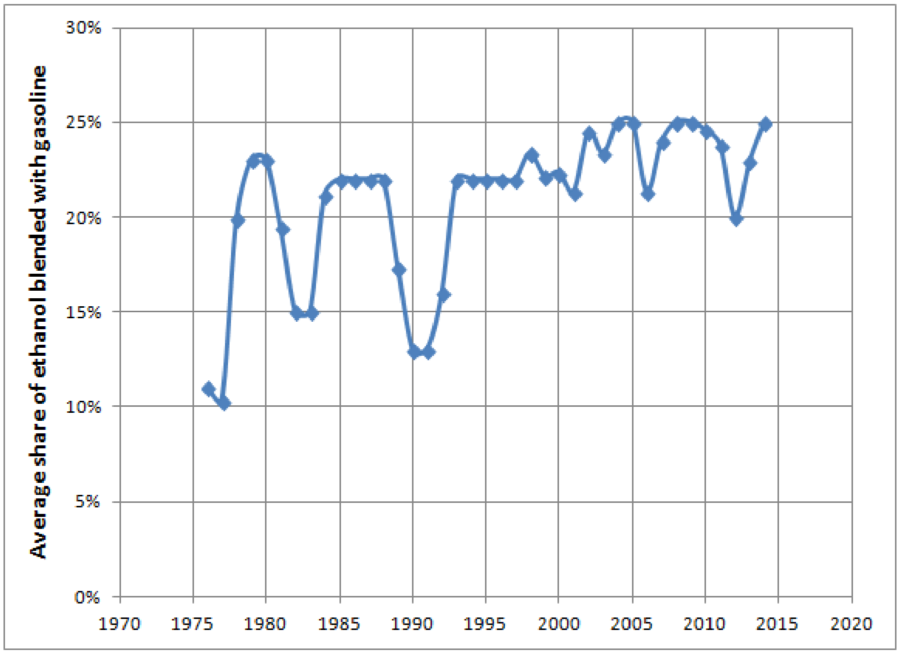
[9] Text based on Walter (2008): Bio-ethanol Development(s) in Brazil; in: Soetaert W. and Vandamme E. (Editors). Biofuels.

[10] At that time, only four main car manufacturers were based in Brazil.

[11] 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).



Source: ALOPAR (2011) and ANP (2014)

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

Moreover, along the years consumers were stimulated to buy neat-ethanol cars due to the lower taxes vis-à-vis 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 fuel price paid by consumers. Currently, six different taxes and contributions have been applied over automotive fuels, being just one equivalent to the value-added tax (VAT). As an example, 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 state of São Paulo (the largest producer and consumer of ethanol in Brazil), the local taxation over hydrated ethanol is close to 12%. In addition, in the state of São Paulo an extra 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).

2.2 Biodiesel

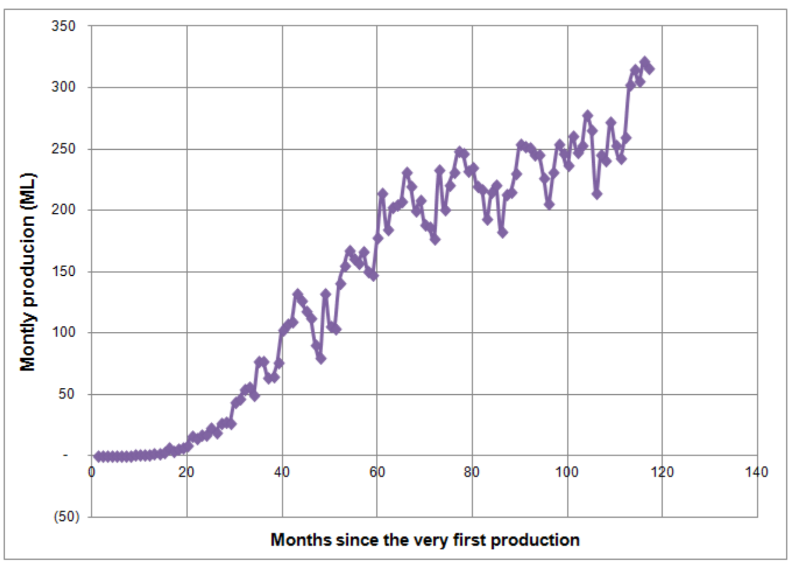
By the end of 2004, Brazilian government decided to implement the so-called National Program of Biodiesel Production and Use (PNPB). The declared targets of the program were generating jobs and income in rural areas and reducing regional inequalities. According to the government, two additional targets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

In 2004 it was defined by law that B2 blends would be mandatory countrywide from January 2008, but this target was changed to B3 blends in July 2008 and enlarged to B4 blends in July 2009. It was initially predicted that only in January 2013 the mandatory mix would reach to 5% of biodiesel (B5), but the target was anticipated to 2010. In mid 2014 it was decided that blend can vary from 5 to 7%, according to market conditions (being these values the minimum and maximum, respectively). In order to reduce diesel imports, in practice B7 blends were immediately implemented. 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 (about 70% in recent years, approximately 20% produced from animal fats, 5% from cotton oil and the balance from other feedstocks).

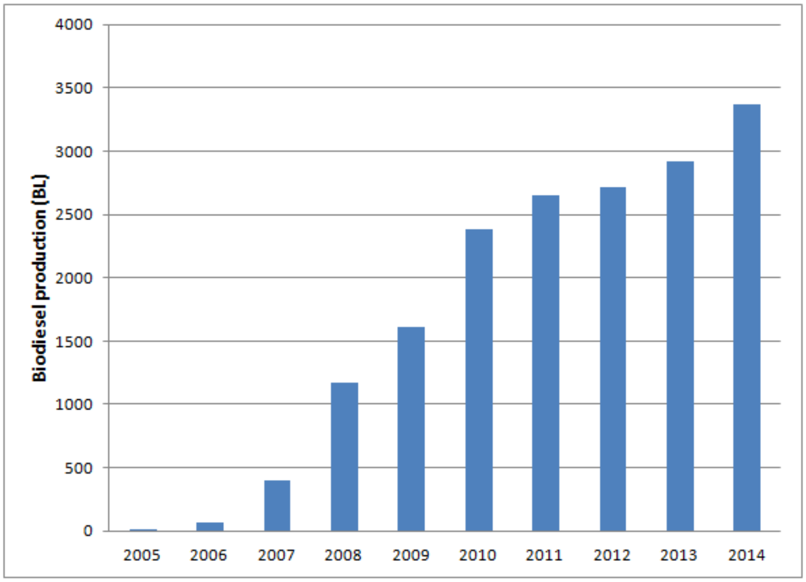
The three main pillars of the PNPB are: (a) the so-called “Social Label”, as specific policies were designed to support subsistence farming systems; (b) reduction of some federal taxes; and (c) biodiesel purchasing auction schemes (Amaral et al., 2008).

The production of biodiesel has been encouraged through purchase auctions organized by ANP. Forty auctions took place since 2007 while the total amount of biodiesel sold surpassed 17 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 monthly biodiesel production from early 2005 to December 2014. In 2014 the production surpassed 3.0 BL and is predicted to reach 4.0 BL in 2015. Figure 2.3 shows the evolution of the annual production from 2005 to 2014.



Source: ANP (2014)

Figure 2.2 Monthly biodiesel production from 2005 to 2014



Source: ANP (2014)

Figure 2.3 Biodiesel production from 2005 to 2014

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 companies that purchase oil-producing crops from small farmers. Total or partial taxes exemptions are granted to biodiesel producers that support family farming.

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 North and Mid-West regions, 30% in South and Southeast regions and 50% in Northeast and Semi-Arid Regions); and

b) Contracts with family farmers establishing deadlines and conditions for raw material deliverance (including prices) and provision of technical assistance to the family farmers.

2.3. Wood resources

During the 1960s, the existence of just 0.5 Mha of plantations and a growing pace in deforestation led to a revision in the ongoing forestry legislation and this result in an updating Forestry Code. In 1967, the IBDF – Brazilian Institute for Forestry Development – was created, together with a national program to foster forestation (based on the 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 due to developments and use of new technologies.During the first half of the 2000s, forested areas held about 250,000 ha/year, an amount still lower than the harvested area. At that time, some timber consumers that faced supply problems imported wood from MERCOSUR countries.

Along the years, several forestry programs have been implemented[12] and they led to increasing annual planted forests through funding at low rates; these programmes also incorporate 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. In the same period the targets for native forests included certification and sustainable management of 15 Mha, 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 the reducing costs. Currently, charcoal use in pig-iron production is concentrated in small independent factories.

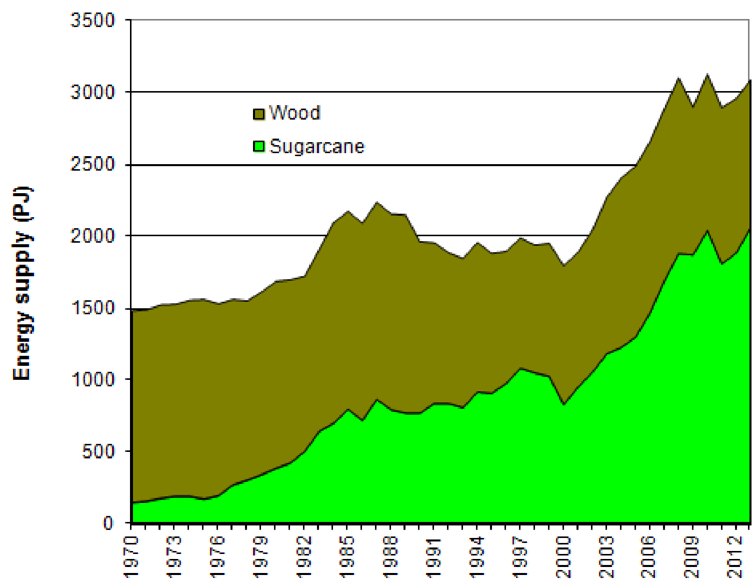
Also in the first half of the 1980s, federal government induced the use of firewood targeting the substitution of fuel oil in industries. The peak of firewood consumption was in 1986 when it reached 280 PJ, and after that it continuously declined; since 2002 firewood consumption in industries has grown again, and reached 323 PJ in 2013.

[12] Such as Pronaf Florestal (Forestry Program for Familiar Agriculture Support), Propflora, Profloresta, and Proambiente.

3. Biomass Resources

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 2013, the contribution of wood and sugarcane to the total energy supply was almost 3,100 PJ, or close to 30% of the total (being about 9.5% from wood and more than 19% from current sugarcane products – ethanol and bagasse)[13]. As shown in Figure 1.5, the contribution of biomass sources to the total energy supply in 2013 reached 2,878 PJ, or 26.4% of the energy consumption; sugarcane bagasse (1,234 PJ), firewood (678 PJ) and ethanol (526 PJ) are the main biomass energy sources.

Despite the economic crisis, 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) with the use of sugarcane bagasse as fuel in cogeneration systems at the mills. 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 the statistics of ethanol production are included in the transformation sector while sugar production in within the food and beverage sector. Figure 3.1 shows the evolution of sugarcane and wood supply from 1970 to 2013.



Source: EPE/MME (2014)

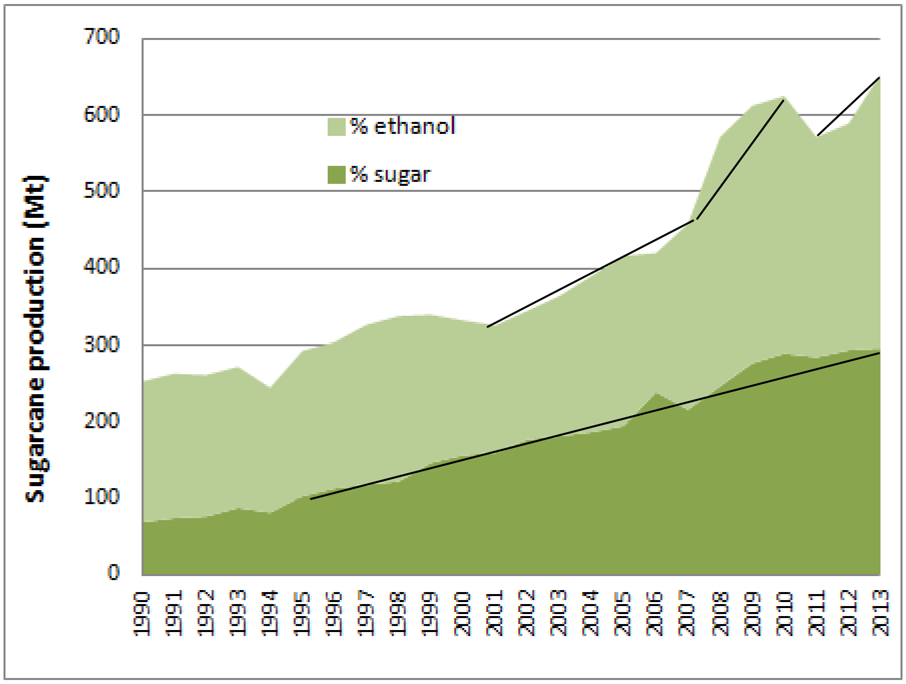
Figure 3.1 Supply of sugarcane and wood from 1970 to 2013

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).

[13] The Brazilian Energy Balance does not present detailed information about biodiesel production, yet.

Figure 3.2 shows the growth of sugarcane production for sugar and ethanol from the harvest season 1990-1991 to 2013-2014. Up to early 2000s the growth of sugarcane production was for sugar production, but this has changed afterwards. Since 2007, no less than 50% of the sugarcane has been used for ethanol production (in some years, 55-57%).



Source: CONAB (2014)

Figure 3.2 Sugarcane used for sugar and ethanol production, from 1990 to 2013

The bulk of sugarcane production is in state of São Paulo, with more than 50% of the total production (55% in 2013), while in the Centre-South region the production represents more than 90%. A small share of sugarcane production is in the North-Northeast region (9% in the harvest season 2013-2014). The mills in North and Northeast regions produce more sugar than ethanol and, thus, ethanol production is even more concentrated in the Centre-South region (MAPA, 2011).

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 generation 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 market opportunities are limited, bagasse is inefficiently used at fuel; at least 50% of the bagasse could be saved in an efficient industrial unit.

At the field, the availability of sugarcane trash (leaves and points of the sugarcane plant) is almost equal than bagasse, but so far a small amount of trash has been used as fuel (mixed with bagasse). 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 in large-scale to be used as fuel; currently, in some regions almost 100% of sugarcane has been harvested without previous burning. 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 can be used as raw material for biofuels production from hydrolysis (or gasification), or even for the production of chemicals. In Brazil, research and development efforts have been more effective on ethanol production through hydrolysis.

3.2 Oil seeds[14]

Despite its favourable conditions and large agricultural tradition, Brazil is not among the major producers of vegetable oils, except soy oil (and cottonseed to a lower extent). Table 3.1 shows data of production of different vegetable oils from 2002 to 2013 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 – 2002-2013

Vegetable oils/data	2002	2006	2010	2011	2012	2013
Soybeans (1,000 tonnes)[1]	5,105	5,970	6,970	7,310	6,760	6,960
(% of world production)[2]	16.8	16.4	16.9	17.2	15.8	15.6
(% of Brazilian production of VO)[2]	77.8	89.9	89.4	89.0	89.0	88.4
Cottonseed (1,000 tonnes)[3]	196	242	454	455	347	396
(% of world production)[4]	5.6	5.0	9.2	8.7	6.7	7.7
(% of Brazilian production of VO)[4]	3.0	3.6	5.8	5.5	4.6	5.0
Palm-oil (1,000 tonnes)[5]	118	170	270	310	340	340
(% of world production)[6]	0.4	0.5	0.6	0.6	0,6	0.6
(% of Brazilian production of VO)[6]	1.8	2.6	3.5	3.8	4.5	4.3

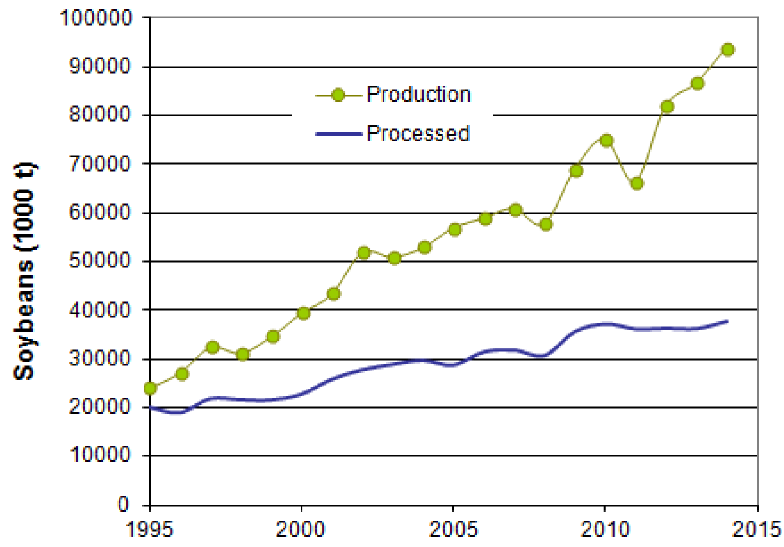
Sources: [1] production data from USDA – Foreign Agricultural Services (FAS-USDA, 2008) + USDA - Office of Global Analysis (OGA-USDA, 2012) + USDA - Foreign Agricultural Services (FAS-USDA, 2014)
[2] calculated regarding world production taken from USDA – Foreign Agricultural Series
[3] production data from Oil World, apud ABIOVE (2008), considering soy oil production from USDA + USDA-Global Agricultural Information Network (USDA-GAIN, 2012) + USDA in Indexmundi (USDA, 2014 B).
[4] calculated regarding data from Oil World, apud ABIOVE (2008), considering soy oil production from USDA + USDA- Global Agricultural Information Network (USDA-GAIN, 2012)
[5] Oil World, apud ABIOVE (2008) + USDA-GAIN (2012) + Ministério da Agricultura Pecuária e abastecimento - Agroenergy Yearbook 2010 (MAPA, 2012) + USDA in Indexmundi (USDA, 2014 B).
[6] calculated regarding data from Oil World, apud ABIOVE (2008) + USDA-GAIN (2012) + Ministério da Agricultura Pecuária e abastecimento - Agroenergy Yearbook 2010 (MAPA, 2012) + USDA in Indexmundi (USDA, 2014 B).
Notes: VO = vegetable oils.

Brazil has a long tradition regarding soybeans production and is currently the second largest producer (after US). Regarding soy oil, Brazil is among the top producers, together with US, China and Argentina. Figure 3.3 shows the evolution of soybean production in Brazil in the period 1995-2014 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 (is almost

[14] This section is based on Rosillo-Calle et al. (2009). The information was updated in this report.

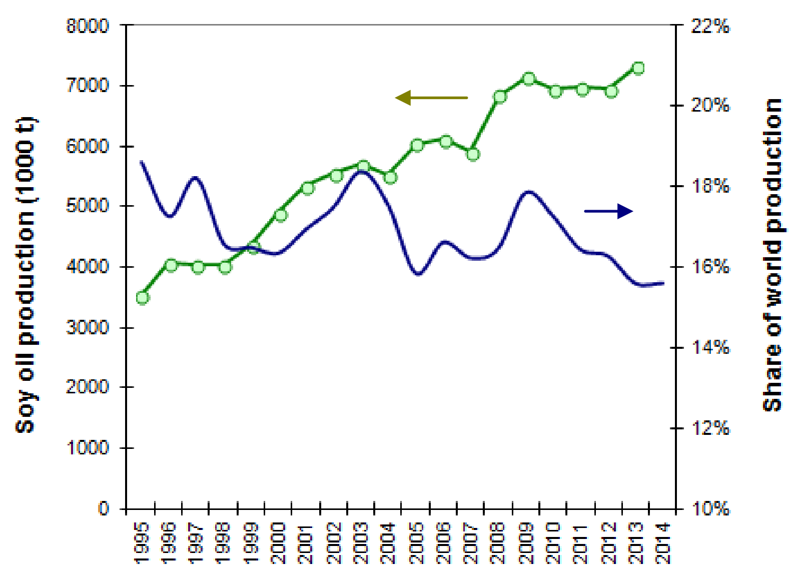
constant since 2010). In fact, the production locally crushed declined from 90% in 1995 to about 40% in 2013-2014. This explains Brazil's lower importance as soy oil producer.

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



Source: FAS-USDA (2014)

Figure 3.3 Soybean production and production locally crushed from 1995 to 2014



Source: FAS-USDA (2014)

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 deforesation, due to the recent expansion of this crop in the Cerrado region, in the central part of Brazil. It is believed that soybeans expansion has caused deforestation in that area and has indirectly contributed to the deforestation in the south of Amazon region (i.e., causing ILUC)[15]. Soybean occupies about 31 Mha in Brazil and is by far the largest crop in the country, covering about 40% of the land occupied with agriculture.

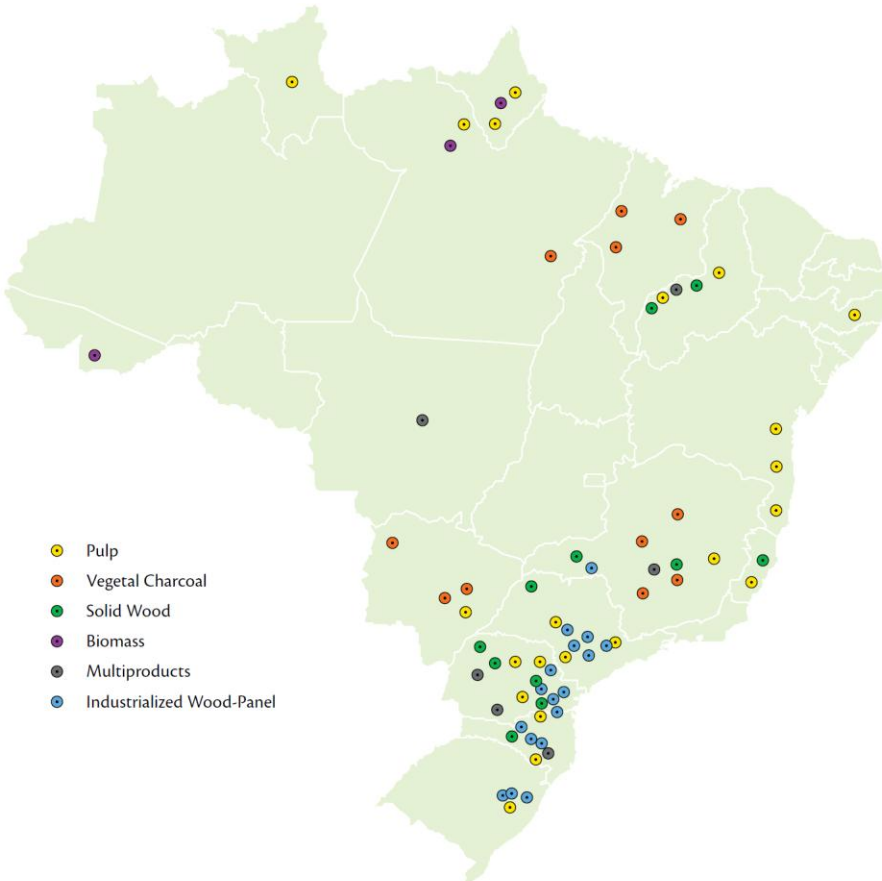
3.3 Forestry resources

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. The production of dedicated forests aims at the pulp and paper industry, timber and logs production, and in a small extent charcoal production[16]. Dedicated forests are mainly of pines and eucalyptus; being estimate as 5.47 Mha planted with eucalypt and 1.57 Mha with pines (IBÁ, 2014).

It is estimated that, in 2013, 35.2% of all the wood produced from planted forests was used in the production of pulp. The production of sawn wood, panels and plywood consumes 23.1%. The remaining amount (41.7%) is destined to the production of industrial firewood, charcoal, treated wood, and other forest products (IBÁ, 2014). The location of the different wood industries based on eucalyptus in Brazil is shown in Figure 3.5.

[15] In order to avoid soy production in deforested areas of Amazon, there is a Programme called "Soy Moratorium": the main soy consumers do not buy soy produced in deforested areas (if any). The producers monitor land use using satellite images and visits on-site.

[16] According to the IBGE (2014), 34.7% of the wood production based on dedicated forests is used in pulp and paper industry, 27.8% for timber and logs, 26.4% as firewood, and 11.1% for charcoal production.

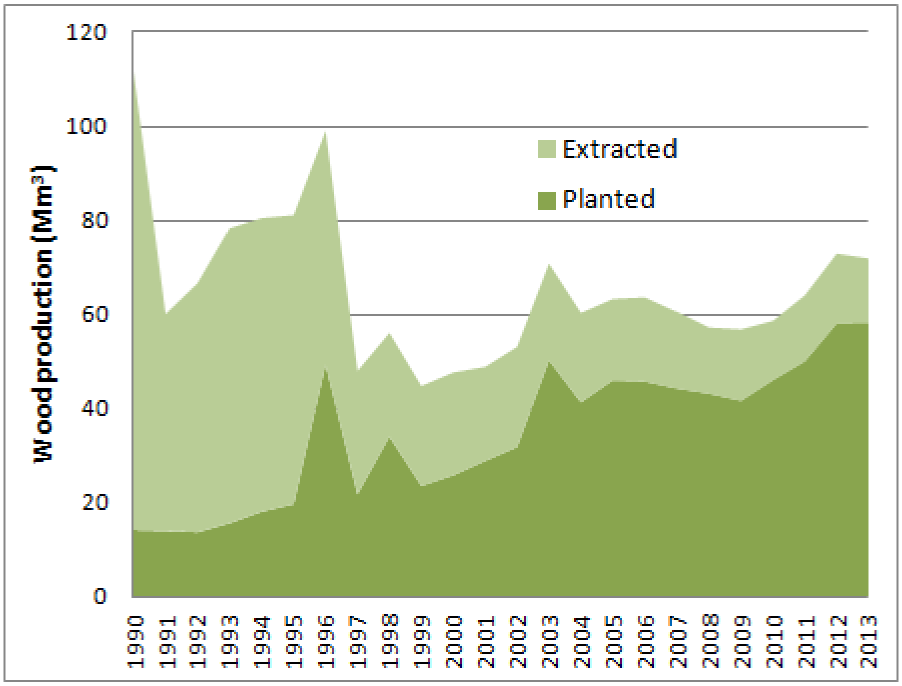


Source: ABRAF (2011)

Figure 3.5 Location of wood (eucalyptus) industries in Brazil, 2010

Figure 3.6 shows the evolution of wood production except for pulp and paper industry (mostly for timber and logs), based on extrativism and on dedicated forests, in the period 1990-2013; the information is based on surveys by IBGE, and is an estimate, mainly regarding extrativism[17]. Data are presented in Annex.

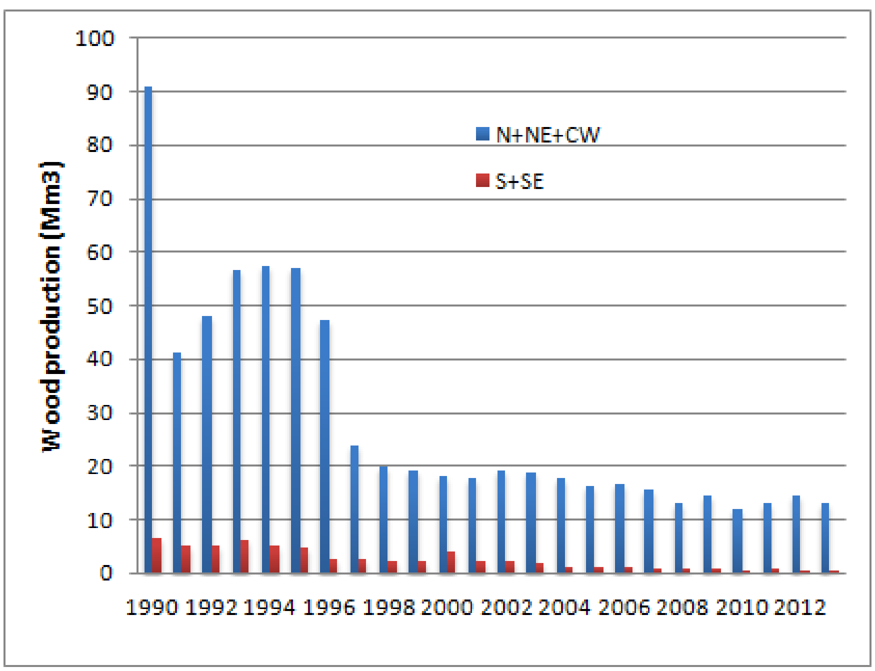
[17] Besides the intrinsic imprecision of such surveys, there is also illegal activity based on deforestation, mainly in the North region.



Source: IBGE (2014)

Figure 3.6 Estimates of wood production in Brazil – 1990-2013

Figures 3.7 and 3.8 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 (79% in 2013; and mostly in Amazon region), and has declined in recent years (based on estimates by IBGE. Reduction was from 98 Mm^3 in 1990 to 22 Mm^3 in 2000 and to 14 Mm^3 in 2013.



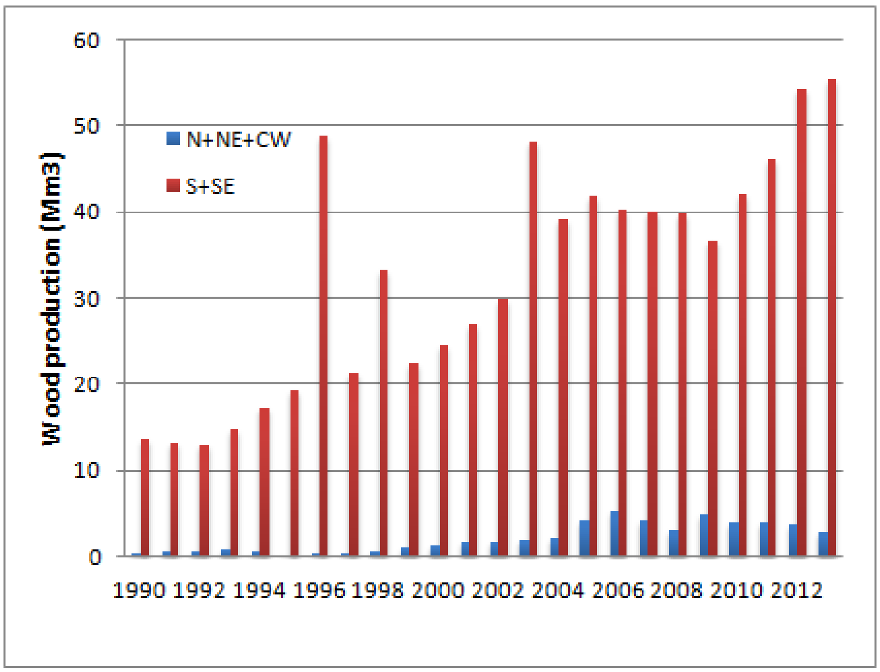
Source: IBGE (2014)

Note: S+SE = South + Southeast regions

Figure 3.7 Estimates of wood production based on extrativism – 1990-2011

Historically, as can be seen in Figure 3.8, wood production based on planted forests mostly occur in the southern part of Brazil, and more specifically in the states of Paraná, Santa Catarina and Rio Grande do Sul (South region) and in the states of São Paulo and Minas Gerais (Southeast region). However, the states of Bahia (Northeast) and Mato Grosso do Sul (Central region) have recently increased the amount of planted forests fostered by four new pulp and paper plants installed there. These two states comprise 17.4% of the overall planted area.

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).

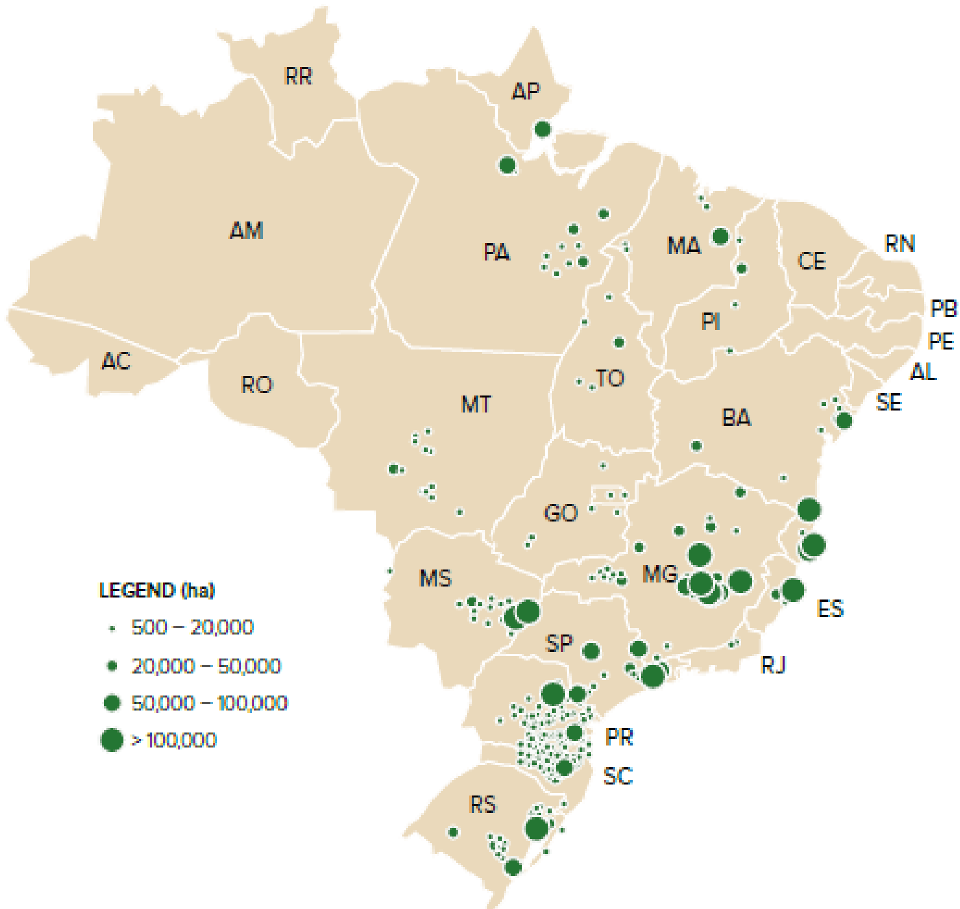


Source: IBGE (2014)
Note: S+SE = South + Southeast regions

Figure 3.8 Estimates of wood production based on planted forests – 1990-2011

In Brazil, the forestry sector tends to expand occupying 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.

The location of the main planted forests of eucalyptus and pines along the country in 2013 is shown in the Figure 3.9.



Source: IBÁ (2014)

Figure 3.9 Location of the main planted forests in 2013

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 2013 was estimated at 87.2 billion litres (REN21, 2014). Brazil is the second largest ethanol producer[18]; in 2013 its production reached 27.6 billion litres, while the domestic consumption as fuel was 22.9 billion litres (EPE, 2014). All motor gasoline sold in Brazil contains 20-27% ethanol on volume basis (E20–E27). 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 only since 1999, after the complete deregulation of the industry, the consumption has raised steadily. Flex-fuel vehicles (FFVs)[19] have been the main driving force of the domestic consumption of hydrated ethanol. In Brazil, FFVs can run with any fuel mix between gasohol (E18–E27) and pure hydrated ethanol (E100). The relative low price of ethanol regarding gasoline and the good technology are the main reasons why currently more than 90% of the new cars sold in Brazil are FFVs.

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 availability of working force, 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 road 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 chock, Brazilian Government 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 laid the ethanol market to difficulties during the 1990s, starting with a shortage of ethanol supply in 1989-1990 that lead 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 1975-2013, according to the fuel option; with the success of FFVs, sales of straight-ethanol vehicles vanished in 2006.

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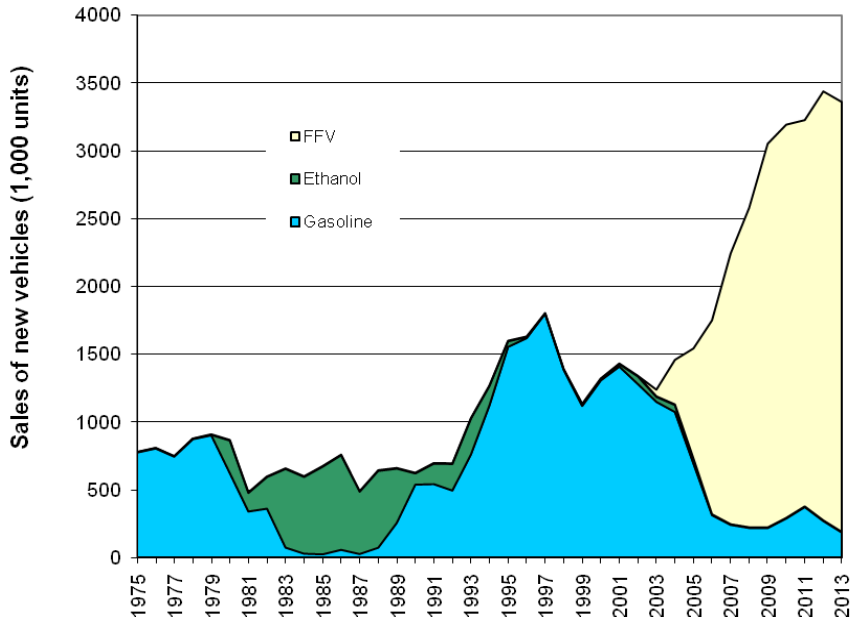
[18] Since 2006 US is the main world producer country.

[19] The first model was launched in March 2003.



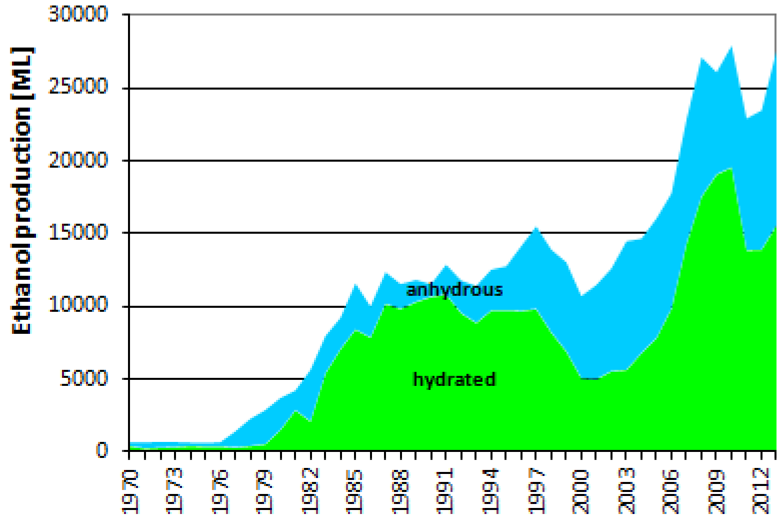
Source: ANFAVEA (2014)

Figure 4.1 Annual sales of new vehicles from 1975 to 2013, according to the fuel option

The PROALCOOL, as initially conceived, finished during the 1990s as long as the government support 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, the main results are due to the boom on sales of vehicles able to run powered by ethanol (FFVs).

Due to an economic crisis of sugarcane sector, that started in 2008, ethanol production was reduced in late years. Currently ethanol (hydrated and anhydrous) covers about 31% of the energy consumption of light-duty vehicles in Brazil (it was 38% in 2010). Most probably, ethanol production will grow in the years to come but at relatively small annual rates.

Figure 4.2 shows ethanol production in Brazil from 1970 to 2013. The production in 2013 was 27.6 billion litres (slightly small than the result in 2010), while the domestic consumption as fuel reached 22.9 billion litres in the same year. It is clear from Figure 4.2 that from 2003 (i.e., after FFVs) to 2009 the production of hydrated ethanol increased continuously while the production of anhydrous ethanol (exported and domestically used in fuel blends) stayed almost constant; this path changed with the production crisis (more anhydrous ethanol was produced).



Source: EPE-MME (2014)

Figure 4.2 Ethanol production in Brazil from 1970 to 2013

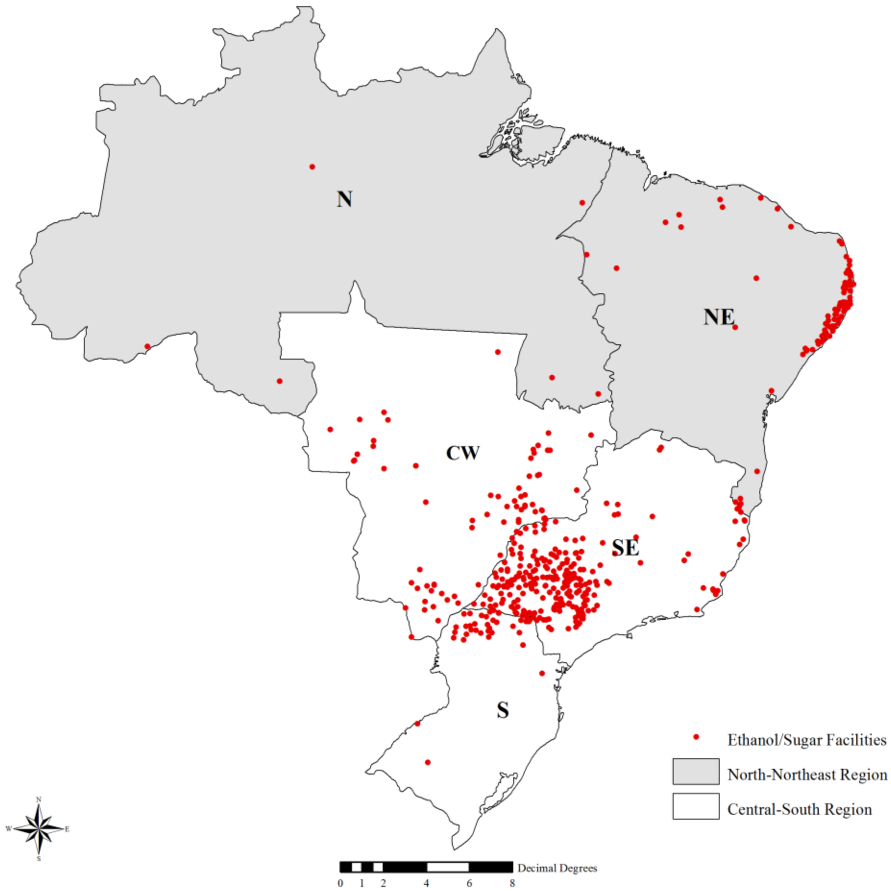
The production of ethanol has faced drawbacks since 2008-2009. The reasons for this are various, and include the following aspects[20]:

- During the financial crisis, starting in 2008, the traditional entrepreneurs of the ethanol sector faced difficulties as they used to finance their activities with short-term loans. Due to financial constrains, less investments were done along the supply chain, and sugarcane yields started to decline (see Figure 4.6);
- As consequence of the bad financial situation of traditional producers, new players in the sector decided to enter the market buying existing assets; as new players, they postponed investments on new industrial plants and also on enlarging the planted area;
- Adverse weather conditions negatively impacted sugarcane production, first with unusual rains during the harvest season 2009/2010, and after with long droughts (2010/2011 and 2013/2014);
- The high prices of sugar in the international market (from the second half of 2009 till July 2011) motivated a slightly shift from ethanol to sugar production, impacting even more the ethanol supply;
- Simultaneously, and most important, from 2008 to 2014 gasoline prices to the consumers have been almost constant (indeed, controlled, in order to avoid inflation), reducing the competitiveness of fuel ethanol (see Figure 5.1).

In 2014 there were about 400 industrial units under operation and some mills with no activities due to financial constrains. Figure 4.3 shows the location of sugarcane mills in Brazil in 2012; it is estimated that 70-80% of the total production is in state of São Paulo and the regions around it. A

[20] Text based on Walter et al. (2014).

small share of sugarcane production is in the North-Northeast region (less than 10% in the last harvest season).

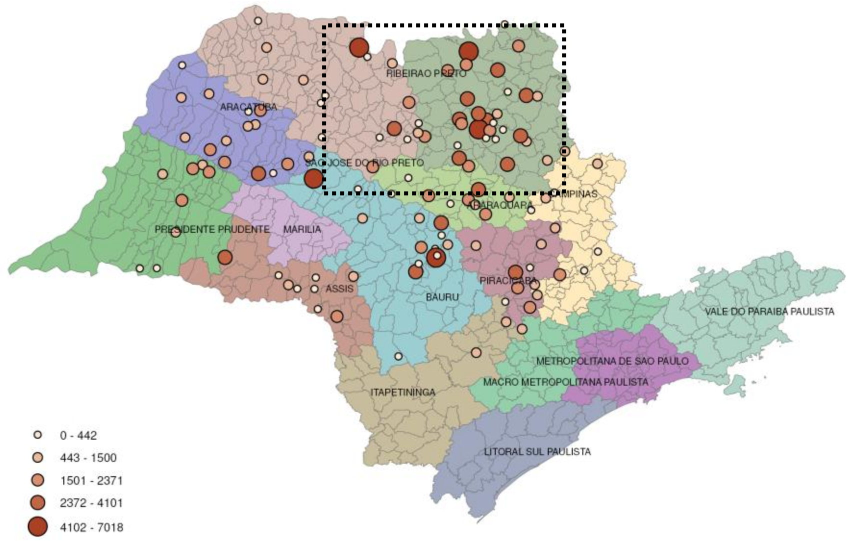


Source: Walter et al. (2014)

Figure 4.3 Existing sugarcane mills in 2012

Most of the mills in Brazil (in 2011, 253 mills) produce both sugar and ethanol in a fully integrated process; these mills have ethanol distilleries annexed and ethanol is produced both from juice and molasses. The main advantages are certain degree of flexibility in production (more sugar or more ethanol, depending on the market demands), the gains in economies of scale in the common systems (cane preparation, juice extraction, utilities), and the synergisms with the integrated operation of the two facilities. The units that produce only ethanol are called autonomous distillery; in 2011 there were 168 mills with autonomous distilleries. A very small number of mills (14 in 2011) and a small share of the installed capacity correspond to units that produce only sugar. "Brazilian model of ethanol production" refers to the combined production of sugar and ethanol.

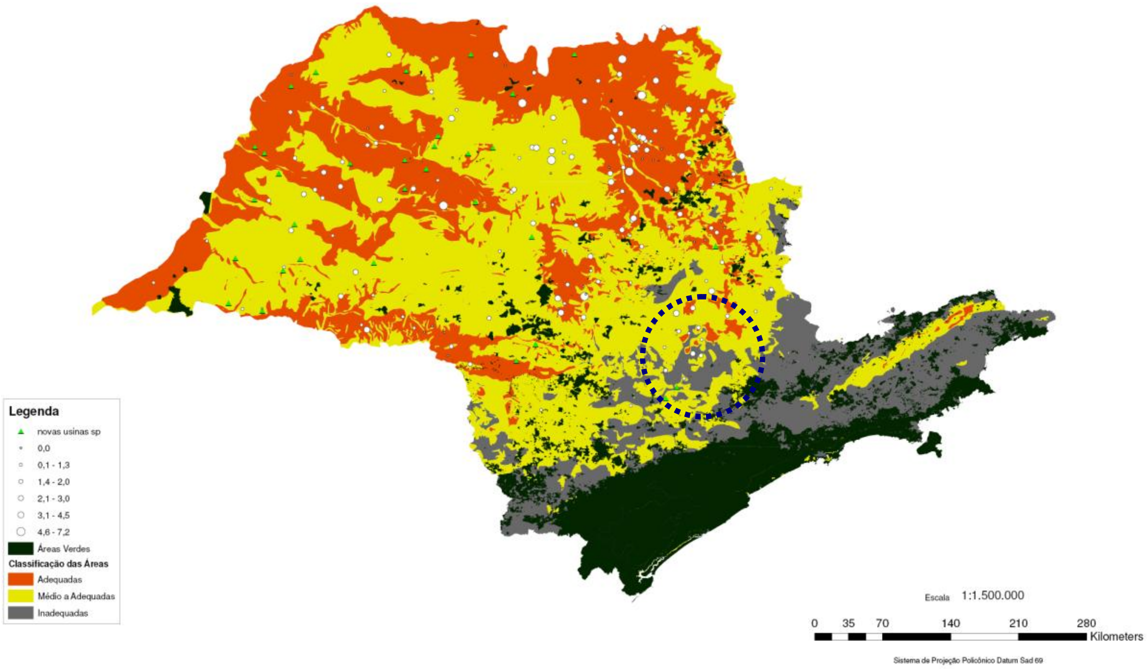
In the state of São Paulo, the region with highest concentration of sugarcane mills – Ribeirão Preto, indicated by dotted lines in Figure 4.4 – has the best conditions for this crop, considering soil quality, weather adequacy, rainfall and topography. This region has high concentration of sugarcane areas 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). In addition to the factors mentioned above, the concentration of sugarcane production in São Paulo and neighbourhoods is also due to the best infrastructure available (including storage facilities, roads, pipelines, harbours, etc.), and the size of the consumer market.



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)

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.



Source: Franco (2008)

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

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

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). 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 (but declining) 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. There are regions is the state of São Paulo (e.g., in Ribeirão Preto) where more than 90% of the sugarcane is harvested without burning.

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

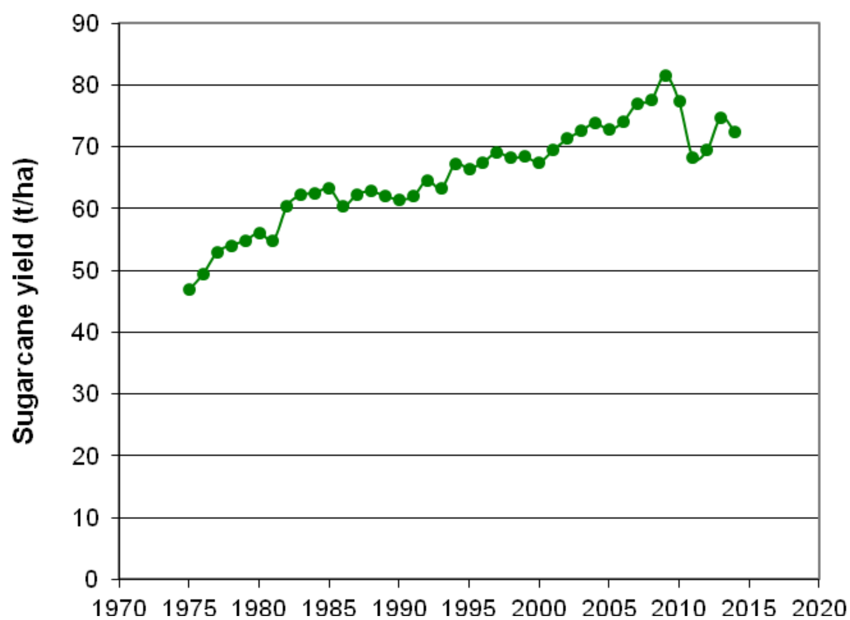
Table 4.1 Profile of sugarcane suppliers in the state of São Paulo – 2006-2007

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 to1	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 in the agriculture and in industry stages, 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 – using best practices – can reach 8,000 litres/ha/year (178 GJ/ha/yr) 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 2013. 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 1.3% per year from 1986 to 2009. As previously mentioned, the drastic reduction of sugarcane yields in the period 2009-2011 (-16%) can be explained by the lack of investments and adverse weather conditions. Since 1975 (and up 2009) yields have grown almost 75% due to the development of new varieties and to the improvement of agricultural practices.



Source: MAPA (2011) and CONAB (2014)

Figure 4.6 Average agricultural yields of sugarcane production in Brazil from 1975 to 2014

4.2 Biodiesel

In 2010 the production of biodiesel worldwide was estimated at about 26.3 BL. Brazil has covered about 11% of the total world production, and is currently the third largest producer, behind US and Germany (REN21, 2014). In Brazil, the biodiesel production in 2013 surpassed 2.9 BL and it is estimated that could more than 3.4 BL in 2014. By the end of 2013 it was estimated that 68% of the biodiesel production has been from soy oil and 27% produced from animal fats (this share increased from about 12% in 2010) and only 4% from other feedstocks, such as sunflower, castor, palm and babassu (ANP, 2014). Brazil is worldwide one the largest soybeans producers and its production comes from plantations, mostly located in the Central and in the South regions.

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 capacity. PETROBRAS has three industrial plants and produced almost 330 ML in 2013.

The authorized capacity of biodiesel production is close to 22 thousand m^3/day (more than 7 BL per year), in 64 industrial units. Table 4.2 shows the production and its distribution in 2013. The large production in South and Central regions is explained by the concentration of soybean production in that part of the country; regarding the production in Southeast the most important feedstock is animal fat (67% of the total regional production by the end of 2013).

Table 4.2 Biodiesel production during 2013 and share of the total production

Region	Production (1000 m^3)	Share of total production (%)
North	62	2.0
Northeast	278	9.5
Central	1,183	40.6
Southeast	261	9.0
South	1,132	38.8
Total	2,917	

Source: ANP (2014)

The high number of biodiesel plants in the Central region is explained by the concentration of soybean production in that part of the country. The state of Goiás has increased production rapidly in recent years stimulated by good infrastructure and closeness to the market (see Table 4.3).

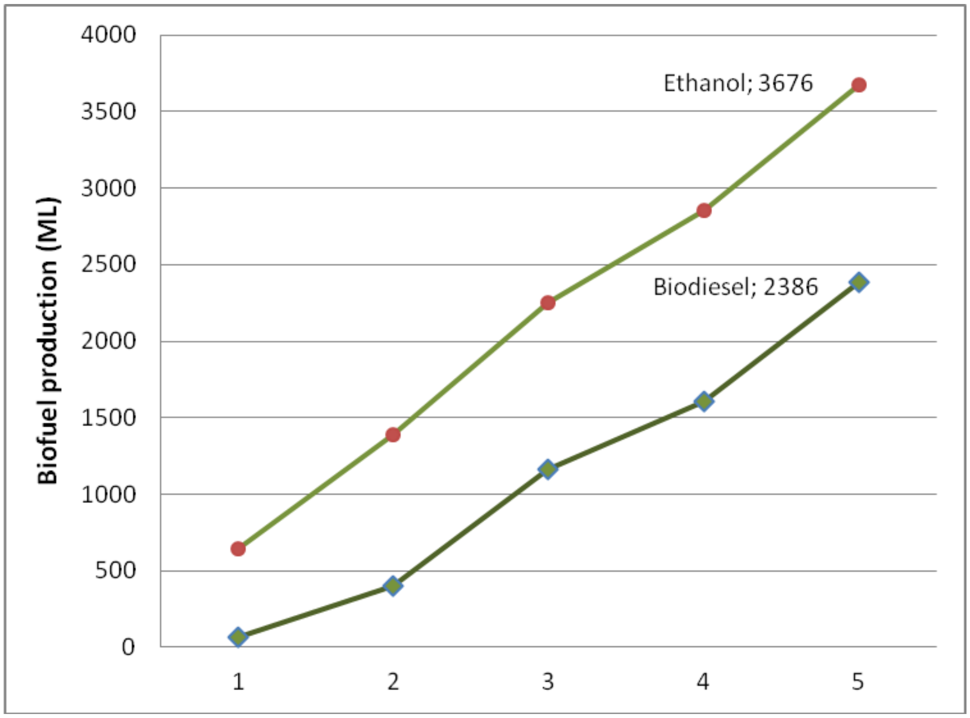
Table 4.3 Accumulated biodiesel production (since March 2005) and production in 2013 (ML)

State	Production in 2013	Accumulated production	Share of accumulated (%)
Rio Grande Sul	883.3	3,960.9	28.4
Mato Grosso	418.5	2,631.4	18.9
Goiás	575.7	2,755.6	19.8
São Paulo	269.3	1,425.6	10.2
Bahia	194.2	870.3	6.2
Brazil	2,917.5	13,943.8	100.0

Sources: ANP (2014)

Due to the changes in the national mandate (biodiesel blends can vary from 5 to 7%, volume basis), it is predicted that the production will surpass 4 BL in 2015, and most probably Brazil will be the second largest producer worldwide. The additional production would be mostly based on soy oil.

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 2010, with a production close to 2.4 BL).



Source: MAPA (2009) for ethanol, and ANP (2011) for biodiesel

Figure 4.7 Production of ethanol (1976-1980) and biodiesel (2005-2009) along the first five years of large-scale production

4.3 Solid biomass

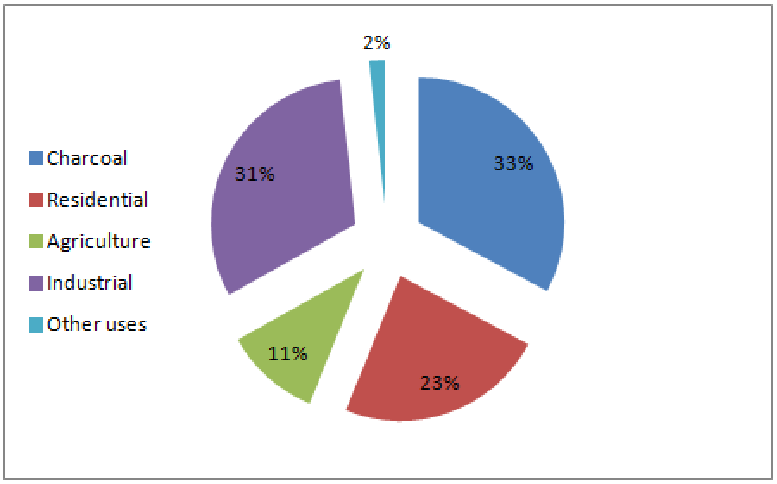
Forestry/wood and sugarcane (residues) are the main sources of solid biofuels in Brazil accounting 3,147 PJ. Firewood includes wood used for charcoal production and also field and timber residues with a share of 32.7% in the total amount. Solid biomass from sugarcane includes bagasse and the so-called trash (top and leaves of the sugarcane plant) with a share of 67.3% on that amount (EPE/MME, 2014).

4.3.1 Firewood and residues

The statistics of the National Energy Balance do not allow the identification of the energy consumption due to firewood and forestry/timber residues in different sectors. In 2013, the total energy consumption of wood products was evaluated as 1,011 PJ, with charcoal representing one third this total. Industrial and residential sectors are also very important consumer, covering 31% and 23%, respectively, of the total wood energy consumption (EPE-MME, 2011). Figure 4.8 shows the main consumers of wood by 2013.

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.

The main use of charcoal has been in the iron and steel industry, where charcoal has partially displaced coal coke as chemical reducer. Generally, planted forests for charcoal production are located as close as possible to the steel and iron plants, which provides to this fuel a competitive advantage. Eucalyptus plantations in the state of Minas Gerais are an example of this regional supply. Other industrial branches that consume charcoal are cement industries and other metallurgic. The consumption in the residential sector, for cooking is also relevant (9.4% of the production in 2013), but with a tendency for stabilizing/declining in recent years due to income growth.



Source: EPE/MME (2014)
Figure 4.8 Wood energy consumption in 2013

4.3.2 Sugarcane residues

Bagasse is by far the main 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. From a statistical point of view, despite the fact that most of the sugarcane mills in Brazil produce both sugar and ethanol (as previously mentioned), its consumption for sugar production is allocated in the industrial sector and the consumption for ethanol production in the energy sector. 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 livestock. Part of the bagasse not used during the harvest period is also discarded after losing quality when the rain season establishes.

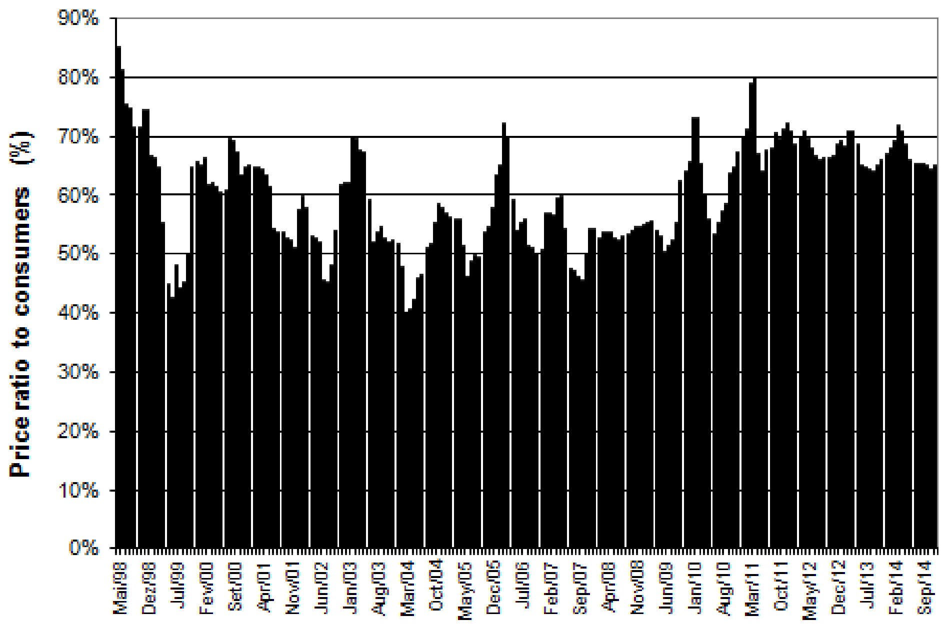
The availability of sugarcane residues at the mills site is expected to grow in the years to come due to the phasing out of cane burning before its harvesting; there is an agreement between sugarcane producers and state governments (e.g., in São Paulo, Minas and Goiás) that define 2017 as the due date for the stopping 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 40% of the so-called sugarcane trash (leaves + tops) should be left at the field, to protect the plant and the soil.

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 December 2014. 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), with many episodes since 2010. 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.

Since 2010 there is a tendency of rising prices of fuel ethanol, reducing its competitiveness vis-à-vis gasoline. General sense, the price ratio is especially high during the off-harvest season in Southeast region, where it's the bulk of the production. The price ratio has been mostly impacted by the decision of the Brazilian government of not adjusting gasoline prices (from 2009 to 2014) according to the international oil prices. The reasons of rising prices of ethanol are related to adverse weather conditions, the lack of investments for enlarging sugarcane production and the high prices of sugar in the international market.



Source: Jornal da Tarde (up to 2001) and ANP (2014) (after 2001)

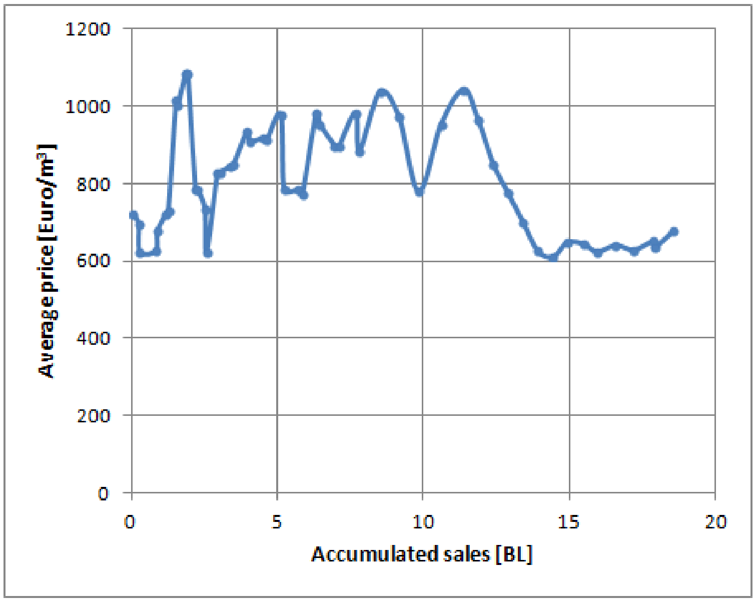
Figure 5.1 Price ratio to consumers (ethanol/gasoline) in the city of São Paulo – March 1998 to December 2014 – based on current prices per litre

5.2 Biodiesel

As an illustration, Figure 5.2 shows the evolution of the average prices paid in 40 auctions of biodiesel carried out in Brazil up to the end of 2014[21]. The total volume sold in these auctions was more than 18.5 BL. Prices paid to producers declined since early 2013 due to the reduction of vegetable oil prices in the international market and the devaluation of the Brazilian currency.

[21] The auctions are organized by the ANP.

The average price paid in an auction by the end of 2014 was 635 Euro/m^3 of biodiesel; at the same time the average price paid to producers of mineral diesel was 460 Euro/m^3, that means an over price of about 38%.



Source: ANP (2014)

Figure 5.2 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 (2014); 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, data come from MDIC (2014). Because they are free from inland transport, taxes and other internalisation costs, those costs were added to them such as the standard of the other prices.

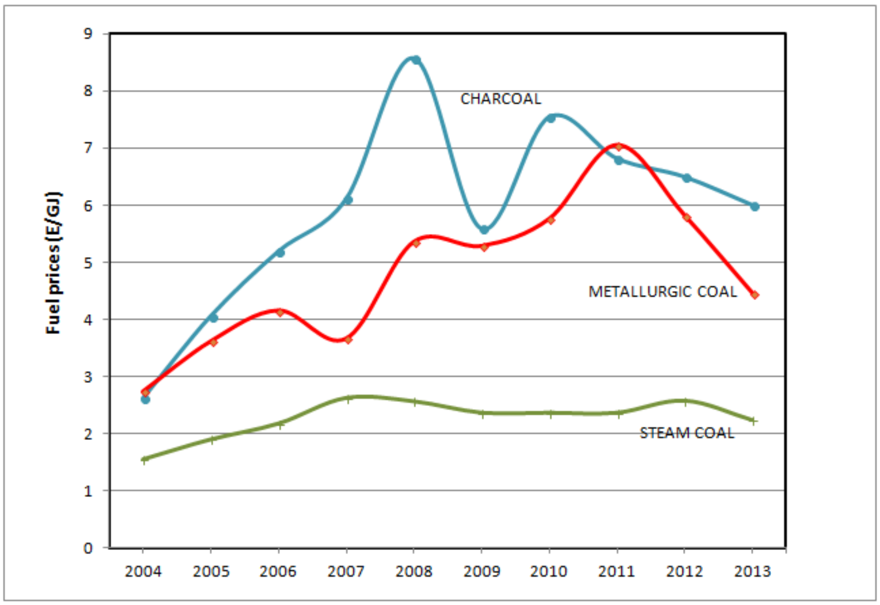
Original prices published in US dollars were converted to 2013 constant dollar using CPI-U index from US. Finally, values in US dollars were converted to Euro using the average exchange rate (parity) found for 2013 (1 Euro = 1.3281 US$).

Figure 5.3 and 5.4 shows the evolution of these prices. Figure 5.3 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, and it’s clear that, just considering market prices, there is no specific advantage for charcoal use. On the other hand, Figure 5.4 allows the comparison of firewood prices to LPG (households use, for cooking) and natural gas and fuel oil (industrial use).

Table 5.1 Fuel prices in Brazil from 2004 to 2013 (Euro/GJ)

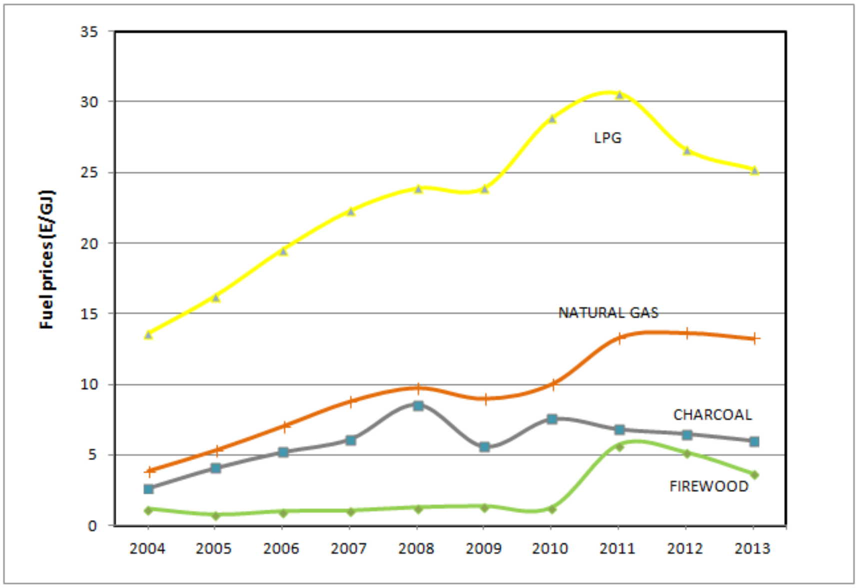
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Charcoal	2,6	4,1	5,2	6,1	8,6	5,6	7,5	6,8	6,5	6,0
Firewood (a)	1,2	0,8	1,0	1,1	1,3	1,4	1,3	5,7	5,2	3,7
Steam coal	1,5	1,9	2,2	2,6	2,6	2,4	2,4	2,4	2,6	2,2
Natural gas	3,8	5,3	7,0	8,8	9,8	9,0	10,0	13,3	13,7	13,3
Fuel oil	5,2	7,0	8,3	9,0	10,6	9,4	11,0	11,9	10,5	10,1
LPG	13,6	16,2	19,5	22,3	23,9	23,9	28,9	30,6	26,6	25,2
Metallurgic coal (b)	2,7	3,6	4,2	3,7	5,4	5,3	5,8	7,1	5,8	4,5

Notes: data are from EPE/MME(2014), except for metallurgic coal which is from MDIC (2014); (a) firewood data up 2010 is from extrativism and after that is from planted forests; (b) metallurgic coal prices are from the imported source.



Source: EPE-MME (2014) and MDIC (2014) for metallurgic coal

Figure 5.3 Average fuel prices for industrial uses in Brazil from 2004 to 2013 (Euro/GJ)



Source: EPE-MME (2014)

Figure 5.4 Average fuel prices for residential uses in Brazil from 2004 to 2013 (Euro/GJ)

6. Biomass Import and Export

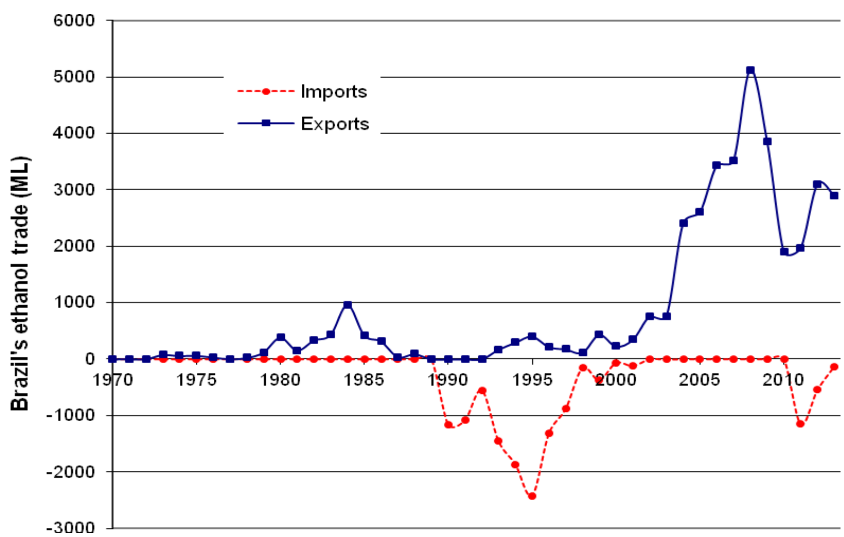
Due to its adequate conditions for biomass production, Brazil is a big potential exporter of biomass. However, what have been remarkable so far – and during some years – were the exports of ethanol, mainly since late 1990s. The production of biodiesel has been just for the domestic market. In what concern solid biomass, there are very small exports of pellets since 2012.

6.1 Ethanol

Even for Brazil, large-scale ethanol trade is a relative new event. As can be seen in Figure 6.1, an expressive amount of alcohol was imported by Brazil during the 1990s, first during the supply shortage of ethanol (1990-1991) and, after, when international sugar markets were favourable for exports (1993-1997). In 2011 and 2012, because of the high costs of domestic production, Brazil imported fuel ethanol from US, but at the same time exported at least two times more fuel (mainly to US, as advanced ethanol).

Traditionally, Brazilian exports of ethanol were focused for beverage production and industrial purposes but since 2004, despite variations, exports of fuel ethanol have been no lower than (almost) 2 billion litres per year. Due to specific conditions, mainly in US, the peak of exports was in 2008 (5.2 BL). There recent tendency is a stabilization of exports on 2.5-3.0 BL.

The reduction of exports after 2008 was mostly due to the drop of direct imports to US, explained by the lower consumption of automotive fuels, the larger production in US and the lower price of gasoline. On the other hand, and certainly very important, Brazil has lost competitiveness due to the higher production costs, the lower supply and, in some years, the evaluation of the Brazilian currency.

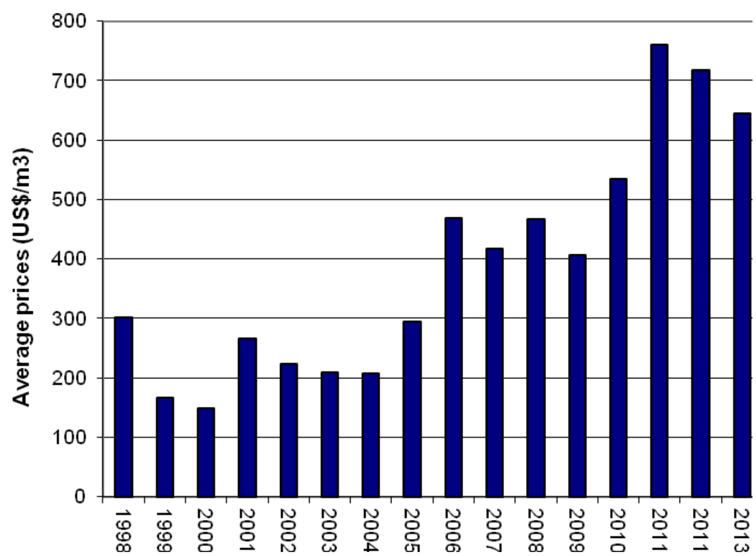


Sources: EPE-MME (2014) and MDIC (2014)

Figure 6.1 Exports of ethanol from 1970 to 2013

As mentioned, Brazil has even imported ethanol in 2011 (about 1.1 BL) and in 2012 (about 550 ML; in 2013 the exports were small and just at the beginning of the year), mostly from US, due to the lower domestic production. It is interesting to note that even though the trade balance with US was positive and the average prices of ethanol sold were higher than the average prices of ethanol bought. Brazil has imported ethanol at the moments the production was low and the prices of the domestic production were high (basically, during off-harvest season in Southeast) and exported ethanol, mostly to US, because the ethanol suppliers in US need ethanol qualified as advanced by the regulation[22].

Figure 6.2 shows the average prices (FOB) received by exporters of ethanol from 1998 to 2011. It can be seen a rise on prices since 2009, partially because of lower supply and partially because of the higher sugar international prices, and a reduction after 2011. Data regarding exports and prices are presented in Annex A.



Sources: MAPA (2009) and MDIC (2014)

Figure 6.2 Average FOB prices of ethanol exported

Historically, 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[23]. As US decided to suspend taxes on imported ethanol since January 2012, the volume traded through Caribbean countries was reduced significantly (464 ML in 2012 and 163 ML in 2013).

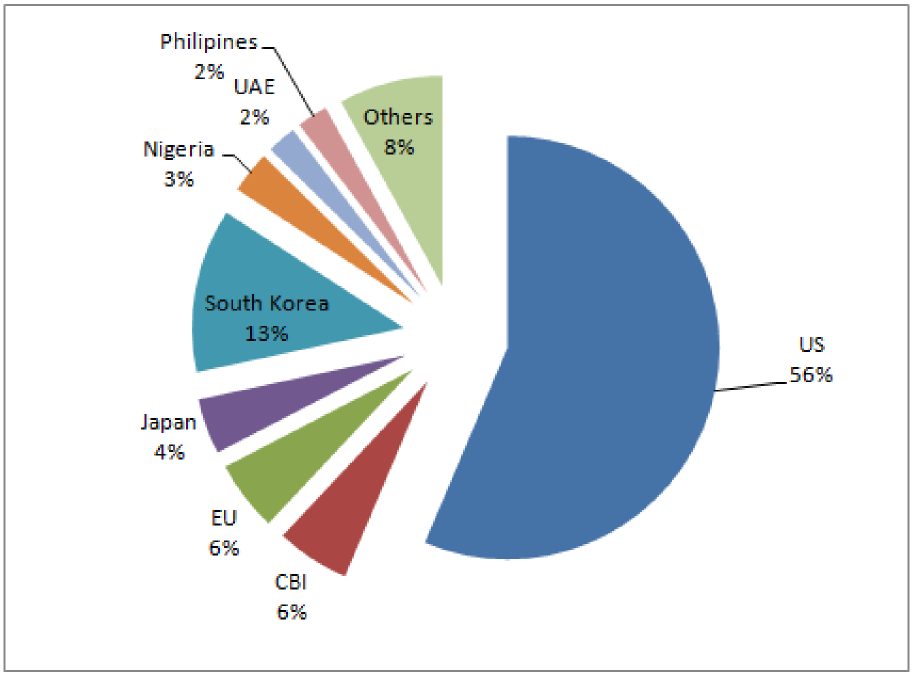
Figure 6.3 shows the main importers of Brazilian ethanol in 2013. More than 1.6 BL were directly imported by United States (56% of the total volume accounted), while more than 160 ML (6%) should have reached US countries. In 2013, South Korea and Japan were also important markets for

[22] Ethanol that allows the reduction of at least 50% of GHG emissions regarding the gasoline life cycle, according to the resolution of RFS2.

[23] 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).

the Brazilian ethanol. Brazil lost competitiveness to US for supplying fuel ethanol to Europe: in 2009 exports summed-up 876 ML and in 418 ML in 2010, but only 156 ML in 2013.

The bulk of the ethanol exported has been shipped in the port of Santos, in state of São Paulo; in 2013, was shipped in Santos.



Sources: MDIC (2014)

Figure 6.3 Main importers of ethanol in 2013

6.2 Solid biomass

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).

According to EPE-MME (2014), Brazil exported few tonnes of charcoal (irregular flows) along the period 1993-2013 (e.g., 5,000 t in 1997 and 28,000 t in 2004). In fact, since 1993 Brazil has mostly imported (probably high quality product) than exported charcoal (almost 3 times more; accumulated imports of 445 thousand tonnes vis-à-vis accumulated exports of 156 thousand tonnes from 1993 to 2013). Exports represent very few regarding final energy consumption (about 0.4% along the period).

Regarding briquettes and pellets, until 2011 it was impossible to precisely estimate the amount of their exports due to the accuracy of trade statistics from the forestry sector: the NCM – Mercosul Harmonic System – Code number 44.01.3000 embraced also sawdust, wood chips, wood waste and scrap, and there was no specific information for briquettes and pellets. The majority of these exports was as wood chips for pulp and paper production abroad. Therefore, all these wood by-products, up to 2011, had embodied the biomass exported and imported for energy purpose unless charcoal (NCM 44.02) and firewood (NCM 44.01.1000) because they receive individual codes (MDIC, 2014).

However, after 2012 it has been possible to identify all the pellet exports because they start to be classified under the individual code NCM 4401.3100 (MDIC, 2014). Most exports were destined to European Union (about 99.5%) and, considering the prices, pellets were probably packed in 15 kg bags. The amount exported from 2012 to the end of November of 2014 is presented in Table 6.1.

Table 6.1 Pellet exports from Brazil from 2012 to 2014

Year	Pellets exports (t)	Pellets exports (TJ)
2012	5.9	0.1
2013	193.7	3.7
2014 (a)	4,355.7	83.8

Source: MDIC (2014)
Note (a): ranging from January to November: 11 months.

7. Barriers and Opportunities for International Trade

7.1 Ethanol

Despite the current drawbacks, Brazil is still an important player in the international trade of ethanol: is worldwide the second largest producer, has been for many years the largest exporter, still has the lowest cost of production, and is, in mid-term, the only country that can significantly enlarge its production aiming at supply the international market.

On the other hand, the production of biodiesel in Brazil is still 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.

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

The 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)). The reduction of exports since 2009 was due to a set of factors, as listed below:

- Larger production of ethanol in US, and further lower demand due to the financial crisis; the surplus of ethanol in US, combined with the subsidies, implied lower competitiveness for the Brazilian ethanol in Europe.
- Lower production of ethanol in Brazil, mostly because of lower production of sugarcane (already mentioned).
- Higher prices of fuel ethanol in Brazil, due to the lower production, higher prices of sugar in the international market and (for some years) high evaluation of the Brazilian currency.

Some years ago it was estimated that the amounted of ethanol exported should reach 10 BL in 2019 (the domestic consumption would be 52 BL in the same year) (EPE, 2011). Both figures seem to be very optimistic for the time being due to current drawbacks of ethanol production in Brazil and also to the reduction of the ethanol market in Europe; a large effort would be necessary to change the tendencies.

7.1.2 Duty-tax barriers[24]

For many years Brazil has blamed against duty-tax barriers imposed by United States and European Union. US imposed till end of 2011 most-favoured nations (MFNs) import duties of 142.7US$/m^3 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 was that these tariffs ensure that the benefits of the domestic US ethanol tax credit do not accrue to

[24] This section is partially based on Walter et al. (2008).

foreign producers (United States International Trade Commission, 2004). During years, US gave special treatment under the CBI agreement but the amount traded under this regime has been far below the 7% cap.

Also under MFN regime, European Union imposes a duty of 192 Euro/m^3 on undenatured alcohol (102 Euro/m^3 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).

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 VLCC[25], 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. 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). Part of the predicted pipelines is under operation since 2013.

7.1.4. Environmental issues[26]

The current drawbacks of ethanol production are circumstantial and 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 were widely recognised, these comparative advantages could be reinforced.

It is recognised that Brazilian ethanol is produced at the lowest cost and its feasibility does not depend on subsidies. However, some 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 (RED-EU). 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%. But even considered direct and indirect impacts of land use change, EPA – the

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[25] Respectively, with transportation capacities of 150 thousand m^3 and 280 thousand m^3.

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

Environment Protection Agency, in US – recognises that the reduction regarding gasoline could be at least 61%.

However, 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 growth of croplands, and more specifically the growth of sugarcane areas, has mainly occurred in lands previously occupied with pastures. In addition, the growth of sugarcane areas did not induce the displacement of cattle herds to other regions of Brazil. 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 for soybean production. On the other hand, there is no evidence that the growth of sugarcane is São Paulo has caused deforestation in Centre-West and in North of Brazil.

Regarding socio-economic aspects of sugarcane production, in a report by Walter et al. (2008) a regional and more detailed approach was adopted based on welfare indicators (e.g. health 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 (sugarcane cropping and industrial conversion to ethanol). The results indicate that in most cases the municipalities in which sugarcane production occurs 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 the impacts on biodiversity, are lower 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

In general, 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. For pellets, for example, there are no mature tradition on production and consumption and it is the very first barrier to be overcome. Despite still existing constraints, some changes may help to decrease the effect of some barriers for international trade.

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. However, in the past two years, both the increase in the pellet prices in Europe and the decrease in the industrial activities in Brazil, built a new scenario for pellet exports. In some cases, mostly near ports and employing industrial residues (furniture, other wooden products), prices obtained for pellet packed in 15 kg bags may compete with those paid by domestic use. From January of 2013 until November of 2014, about 4,550 tonnes were exported.

Exchange ratio –The devaluation of US currency vis-à-vis Brazilian Real (that has started in 2004) reduced the earning of local exporters for a long time. However, since middle of 2011 exchange rates have presented the inverse trend. More specifically, since July of 2011 Brazilian Real reached a devaluation of almost 70%.

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.

As presented on Chapter 3, Brazil accounts presently with 7.6 Mha of planted forests. Trends in certification have presented improvements in the past years. The certified area in 2013 comprised about 5.4 Mha, or more than 70% of the total area (IBÁ, 2014). External market for furniture and other wooden products became reduced after 2008 and certification now is not only an attribute but also a precedent condition to export. Thus, in general residues from that industry are certified and may be used to produce briquettes and pellets.

Logistics – Since an assessment made in 2005, logistic keeps as the main barrier for exporting solid biomass. Most of planted forests are located at places where freight up to maritime ports is quite expensive, 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 for the case studied it was not feasible to transport residues by trucks for more than 200 km far from the pelletization units located at the Paranaguá port.

Fluvial transport may be a solution for the Northern and Centre-Western regions 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 transportation 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 transportation costs in 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 sites with biomass availability, Dolzan and Walter (2006) found overall logistic costs ranging from 65% to 90% vis-à-vis the wood chips production costs. 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 conditions 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. 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. Since 2006, at least two big companies for both energy and pulp purposes have well structured and specialized ports and facilities, such as Amcel, in Santana – state of Amapá, in the North, and Bianchini (Tanac), in state of Rio Grande, in the South. These companies have presented highly competitive prices at outstanding levels.

8. Concluding Remarks

Biomass production and consumption has a long history in Brazil and the country has both potential to enlarge the share of biomass in its energy matrix and to be a big player in the bioenergy international trade arena.

For more than 35 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. However, since 2009 Brazil ethanol production has faced difficulties and just in 2013 it was possible to recovery the production level of 2009. Anyhow, this is a good indication that bioenergy market is still fragile all over the world, and policies shall be consistent in long term. Regarding exports, the perspectives are not negative, but the extent of the international trade, and of Brazil's participation in it, will depend on a set of factors.

The Brazilian experience with biodiesel is more recent (less than 10 years), but even though the results achieved so far are remarkable. However, the rationale of the biodiesel program tends to be contested as the production has been mostly based on soy oil and, in practical terms, financial support has been received by 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, and sustainability of biodiesel production has yet to be assessed. A good sign is the enlargement of biodiesel production from animal fats, which is a feasible and rational option. The B5 blends are consolidate, and since 2014 B7 is the maximum allowed. There is no perspective for exporting biodiesel in short-term and the domestic market will be enough for making Brazil the second largest producer worldwide.

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, as well as for cogeneration units (at the sugar and ethanol mills) based on sugarcane bagasse. However, for charcoal production it is necessary to set priority on sustainability. There is also potential for pellets production, both for the domestic and for the external markets, but in this case it will be necessary to overcome barriers such as logistics, exchange ratio and certification. The exports undertaken in 2014 may help to obtain tradition on pellets production and consumption, but the industry is just starting in Brazil.

Specifically regarding trading, there are two challenges for Brazil. The first drawback to be addressed is regarding logistics constrains, which impact the feasibility of solid biomass (e.g., pellets) and ethanol exporting. Logistic constrains have been addressed by producers and traders in case of ethanol, e.g., with investments on pipelines and on maritime terminals but there is still a lot to do in order to get the adequate infrastructure.

The second challenge for exporting is improving sustainability of biomass (and biofuels) production. Along the years there is a growing perception that rather being 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 principles and 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 Final energy consumption – Brazil, 2000 and 2007-2013 (PJ)

Energy sources	2000	2007	2008	2009	2010	2011	2012	2013
Natural gas	298	649	700	641	707	746	764	778
Coal	95	124	129	101	136	156	150	152
Wood	571	683	706	694	714	687	690	678
Sugarcane bagasse	560	1120	1201	1191	1259	1144	1188	1234
Other primary renewables	126	208	221	233	253	255	249	266
Other gases	52	58	50	50	60	62	60	58
Coke	272	281	281	222	315	344	335	327
Electricity	1194	1484	1542	1534	1673	1732	1795	1859
Charcoal	202	262	260	166	195	201	193	174
Ethanol	270	376	494	525	529	473	441	526
Other secondary	9	9	8	8	10	9	9	9
Oil products	3527	3757	3879	3876	4249	4485	4722	4835
Diesel	1235	1475	1584	1560	1737	1823	1934	2043
Fuel oil	398	272	263	250	207	185	166	169
Gasoline	558	600	611	616	736	875	1026	1024
Liquefied petroleum gas	328	311	318	312	322	335	336	348
Naphtha	339	326	288	308	318	309	307	275
Kerosene	136	111	119	119	134	150	158	152
Other secondary from oil	343	454	445	465	467	492	481	498

Source: EPE/MME (2014)

Table A.2 Final energy consumption by sectors – Brazil, 2000 and 2007-2013 (PJ)

Sectors	2000	2007	2008	2009	2010	2011	2012	2013
Residential	866	932	952	968	987	974	995	994
Industry	2563	3397	3415	3190	3583	3714	3714	3697
Transport	1984	2429	2631	2639	2919	3098	3309	3481
Energy sector	538	881	1033	1001	1016	928	957	1094
Others	650	777	826	818	854	874	913	946
Total	6601	8417	8857	8617	9358	9589	9888	10212

Source: EPE/MME (2014)

Table A.3 Energy consumption in industry – Brazil, 2000 and 2007-2013 (PJ)

	2000	2007	2008	2009	2010	2011	2012	2013
Natural gas	162	339	354	304	388	419	412	408
Coal + coke	391	405	410	323	450	499	485	479
Oil products	579	539	522	523	510	536	527	536
Electricity	528	694	710	672	732	754	755	756
Biomass	860	1375	1373	1324	1446	1448	1478	1463
Others	42	46	46	44	56	58	56	54

Source: EPE/MME (2014)

Table A.4. Energy consumption in transport – Brazil, 2000 and 2007-2013 (PJ)

	2000	2007	2008	2009	2010	2011	2012	2013
Gasoline	555	598	609	614	734	872	1024	1021
Ethanol	244	361	461	494	504	449	415	498
Diesel Oil	1009	1205	1270	1243	1359	1430	1514	1609
Biodiesel	-----	14	31	44	66	75	79	84
Others	176	251	259	245	256	272	278	269

Source: EPE/MME (2014)

Table A.5. Firewood supply and consumption – Brazil, 2000 and 2007-2013 (PJ)

	2000	2007	2008	2009	2010	2011	2012	2013
Production	966	1198	1224	1030	1089	1089	1075	1029
Charcoal	389	508	505	327	362	390	373	338
Residential	275	327	323	315	305	272	271	240
Agriculture	69	99	106	101	106	102	101	111
Industrial	224	254	274	275	300	308	313	323

Source: EPE/MME (2014)

Table A.6. Charcoal production and consumption – Brazil, 2000 and 2007-2013 (PJ)

	2000	2007	2008	2009	2010	2011	2012	2013
Production	212	269	268	172	200	207	198	179
Imports	0	0	0	0	0	0	0	0
Exports	0	0	0	0	0	0	0	0
Iron + Steel	174	226	222	134	165	168	161	146
Residential	17	22	22	24	21	20	20	17

Source: EPE/MME (2014)

Table A.7. Wood production (except for charcoal and firewood) based on planted forests and extrativism (Mm^3)

	Planted forests		
	Timber and logs	Pulp and paper	Extrativism
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
2008	43.1	58.1	14.1
2009	41.6	65.3	15.2
2010	46.0	69.8	12.7
2011	50.0	75.9	14.1
2012	58.0	73.9	14.1
2013	58.2	72.6	13.7

Table A.8 Exports of ethanol from 1998 to 2013 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	3,296	406
2010	1,900	534
2011	1,968	760
2012	3,098	717
2013	2,903	644