A Brief Account of Brazil's Biomass Energy Potential[1]

Uma Breve Análise do Potencial da Biomassa no Brasil

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Abstract: Biomass has and will continue to play a major role worldwide as a source of energy, both in traditional and modern applications. For bioenergy to continue to play this role, it must provide modern consumers what they want, i.e., affordable and convenient fuels such as lighting, power, etc. This requires major changes in the way energy is produced and used. Brazil is endowed with huge biomass resources which remain largely untapped. Brazil is unique in that it is one of the few countries where bioenergy is used in large industrial scale applications. This paper presents an overview of the most important aspects of bioenergy in Brazil with emphasis on resources (woodfuels, charcoal, residues, sugarcane and ethanol, biodiesel) and a brief note on flex-fuel vehicles (FFVs). It emphasises the need to modernise the production and use of bioenergy. Biomass resources can greatly be enhanced with the development of new conversion technologies.

Key words: Bioenergy, Brazil, biomass resources, and fuel ethanol.

Resumo: A biomassa é uma importante fonte mundial de energia para aplicações tradicionais e modernas. Para que continue a desempenhar este papel, é necessário que a bioenergia ofereça aos consumidores modernos combustíveis de baixo custo e convenientes, como luz e energia. Isto exigira mudanças significativas na forma como a energia é produzida e usada. O Brasil possui enormes recursos de biomassa que permanecem não-explorados na sua maioria. É um país singular por ser um dos poucos países onde a bioenergia é usada em aplicações industriais de grande escala. Este trabalho apresenta uma análise dos mais importantes aspectos da bioenergia no Brasil, enfatizando os recursos disponíveis (combustível da madeira, carvão, resíduos, cana-de-açúcar, etanol e biodisel) e uma breve informação sobre *flex-fuel vehicles* (FFVs). Enfatiza também a necessidade de modernização e uso da bioenergia. Os recursos da biomassa podem ser altamente incrementados através do desenvolvimento de novas tecnologias de conversão.

Palavras-chave: Bioenergia, Brasil, recursos de biomassa e etanol combustível.

1 Introduction

Bioenergy is a broad term embracing a large range of feedstock and can be classified into three main categories: i) woodfuels, ii) agrofuels, and iii) urban waste-derived fuels. Bioenergy can also be classified according to a chosen technology route:

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i) traditional applications (i.e. firewood and charcoal), and ii) modern uses (i.e. electricity generation and CHP). Modern applications are rapidly replacing traditional uses, in particular in industrial countries (e.g. in Finland and Sweden), with about 20% of their primary energy being generated from biomass; and in Austria with 60% of district heating. Bioenergy is not a transition fuel as it has often been portrayed, but a fuel that will continue to be the prime source of energy for an increasing number of people in the foreseeable future (Rosillo-Calle, 2004).

2 Biomass Potential

There have been many attempts to quantify the potential of bioenergy, but with large variations due its complex nature; this involves many and different factors, ranging from resource availability, techno-economics, productivity issues, conversion technologies, as well as ecological, social, cultural and environmental factors. In addition, there is considerable uncertainty with regard to the potential role of energy forestry/crop plantations, since residues (all sources) have limited possibilities. The plantation potential ranges from 100 Mha to over 1,300 Mha. A study (IPCC-TAR, 2001) has estimated the global potential at 440 EJ yr^{-1} (10.12 Gtoe); it assumes all agricultural land not needed for food production (1.28 billion ha or 9.70% of the total world land), will be used for forest plantations. This scenario is unlikely to be achieved since there are other alternatives (wind, solar, cleaner fossil fuels, etc) that need to be taken into consideration. Two fundamental factors could enhance the bioenergy resource base: i) increased and sustainable productivity; and ii) the development of new conversion technologies and processes.

Biomass resources are potentially the world's largest and most sustainable energy source. Hall & Rao (1999) quoted a potential renewable resource comprising 220 billion oven dry tonnes (odt), or about 4,500 EJ of annual primary production and an annual bioenergy potential of about 2900EJ, although realistically, only 270EJ may be considered available on a sustainable basis and at competitive prices. Various other scenarios have estimated the potential contribution from bioenergy for the period 2025-2050 between 67EJ and 450EJ, for the research focus (RF) scenario, and from 28EJ and 220EJ for the demand driven (DD) scenario, respectively. The share of the total final energy demand lies between 7% and 27% (Hoogwijk, 2001). For comparison, current use is about 55EJ.

Therefore, the main problem is not availability of biomass resources, but sustainable management, competitive and affordable delivery of energy to those who need it in order to provide them with modern energy services. This implies that both production and use of bioenergy must be modernised in all its forms.

Bioenergy is not a transition fuel as it has often been portrayed in the past, but a fuel that will continue to be the prime source of energy for many people in the foreseeable future. For example, an IEA (2002) study concluded: *"Over 2.6 billion people in developing countries will continue to rely on biomass for cooking and heating in 2030 (…) this is an increase of more than 240 million from current use. In 2030 biomass use will still represent over half of residential energy consumption…"*

3 Current Contribution

Bioenergy is the most important renewable energy (RE) resource and currently provides about 55EJ, mostly in the form of residues (woody and herbaceous); and also from plantations, as is the case of Brazil. This compares with wind power (the faster growing RE source) with an estimated installed global capacity of 150 GW by 2012[1/]. The future contribution of bioenergy will increasingly be in modern applications. Wood is the most important source, mostly as residues from the timber industry, plantations, traditional forests, etc. The greatest potential, and uncertainty depend on the potential contribution from dedicated energy plantations.

A major remaining challenge is how best to tackle the problems posed by the traditional uses of bioenergy, i. e., low combustion efficiency and health hazards, as well as low productivity. For bioenergy to have a future it must provide people with what they want, i. e., affordable and convenient fuels such as lighting, power, etc. This requires major changes in the way energy is produced and used. Thus, considerably more efforts are still needed to integrate policies, technologies, management issues and markets to achieve these goals.

Traditional and modern applications of bioenergy[2/] are often intertwined and difficult to distinguish. Evidence shows that bioenergy is used by low and high-income groups in many parts of the world and modern uses of bioenergy are often complementary to traditional fuels (FAO, 1997). But as living standards increase, people and many cottage industries are increasingly shifting to more convenient sources of energy.

4 Biomass energy in Brazil

A particular characteristic of Brazil is the large industrial scale applications of biomass energy (see Rosillo-Calle et al, 2000). Good examples are ethanol from sugarcane, charcoal production from eucalyptus plantations, cogeneration of electricity from bagasse, and the pulp and paper industries (sawdust, black liquor, etc). This is due to a combination of factors ranging from easily available and inexpensive biomass resources due to favourable climatic conditions, land availability (Brazil's continental size), existence of many isolated areas unconnected to the national grid, large proportion of unemployed population reflected in cheap labour, and historical experience with large-scale industrial applications of biomass energy.

Yet, at the same time and despite this potential, the proportional contribution of biomass as a primary energy source has been declining for decades, reflecting social, economic and political priorities, not only in Brazil, but worldwide. However, in absolute terms, RE, including biomass have seen its total contribution increased from 65 Mtoe in 1990 to 69.5 Mtoe in 2001[3/]. This is due to the rapid increase in energy demand, i. e., from an index of 100 in 1985 to over 150 in 2000. It is within this new reality that biomass energy contribution needs to be analysed. Table 1 summarises biomass-base power plants in Brazil. The total installed capacity was 2.73 GW of which bagasse represented 1.93 GW.

Brazil's large biomass energy potential remains largely unaccounted and unexploited; the country is in a unique and privileged position to increase biomass energy offering considerable potential for energy diversification, particularly in modern industrial applications. True, biomass energy is expanding and new capacity is being added annually (see www.aneel.gov.br/applicacoes/Atlas/biomassa/).

[1/] See Elize Vries, Renewable Energy World, v. 7, n. 3, p. 60-70, 2004.

[2/] Traditional uses of biomass energy include household and cottage industrial applications, but used very inefficiently. Modern applications include household, cottage and other large industrial applications using modern and efficient technologies to provide modern services (see Goldemberg & Coelho, 2003).

[3/] This takes into account the new conversion factor used by BEN in 2002.

Table 1 – Biomass-based power plants installed in Brazil (2003)
Quadro 1 – *Poder energético da biomassa de plantas utilizadas no Brasil (2003)*

Fuel	Number of plants	Power (kW)	%
Black Liquor	11	649,230	23.58
Rice straw	2	6,400	0.23
Sugarcane bagasse	191	1,953,927	70.96
Wood residues: sawdust, shavings, trim, bark, etc.	17	116,002	4.21
Biogas	2	20,030	0.73
Charcoal	1	8,000	0.29
Total	224	2,753,589	100

Source: MME (2003).

4.1 Woodfuels

Brazil has the world's largest reserves of natural forests with about 670 Mha of some type, including 300 Mha of broadleaves out of a total land area of 851 Mha. This represents an enormous potential, at least in theory, i.e., it is estimated that a minimum of 400 Mt per year or 8 EJ yr^{-1} (all sources)[4/] of woodfuels could be available countrywide, on a sustainable basis. Production is well below this minimum, and even modest compared with other countries. In practice, however, this potential may remain largely untapped for the following reasons (Rosillo-Calle & Moreira, 2004):

- Demand for traditional woodfuels is declining rapidly in Brazil, reflecting socio-economic and energy changes.
- Large-scale use of woodfuels would be only possible in advanced combustion or gasification plants. However, these plants are more likely to use plantations rather than natural forests.
- In most cases, large-scale use of woodfuels from natural forest may not be economically feasible because of long distances from main demand centres, unless used to supply small centres or industries.
- Environmental and ecological limitations, i.e., availability of good land.
- High financial and capital costs.

Woodfuels, timber and other related activities employed about 2 million people in Brazil in 2001, including half million in plantations. The forestry industry is a major economic activity and represents 4.5% of Brazil's GDP, equivalent to about $28 billion (PAIM, 2002). Woodfuels are still widely used in rural areas and in many cottage industries i.e., c.7000 ceramic industries, though at low efficiencies. This is a complex issue which involves many changing and interrelated socio-economic issues, i. e., there is a strong connection with the availability and price of natural gas and electricity triggered off by the process of urbanization.

4.2 The charcoal sector

Charcoal is produced in large quantities, but estimating global charcoal production is extremely difficult since in most cases it is an integral part of the informal economy of

[4/] This figure assumes 1/tonne woodfuel per ha/year, collected on a sustainable basis and 20 GJ ton^{-1}.

many developing countries, characterized by small scale operations involving a very large number of small farmers and poor rural people. Estimates vary from 26 to over 100 Mt (104 to 400 Mm^3) of charcoal produced annually worldwide (Rosillo-Calle & Bezzon 2000). The main charcoal producers are Brazil and South Africa.

Contrary to the general view, charcoal consumption has increased in recent years and is becoming an important source of energy for people in rural and urban areas of many developing countries. It is estimated that over 300 million people worldwide use charcoal as their primary source of energy. As living standards increase, people in urban and peri-urban areas, together with many cottage industries, shift from manure, firewood and agricultural wastes to charcoal. Various aspects are worth emphasising with regard to traditional charcoal production:

- The enormous socio-economic importance of charcoal production and use in developing countries. Hundreds of thousands, even millions of people depend totally or partially on this activity.
- The low biomass to charcoal energy conversion efficiency and technology base (12% in Zambia, 11-19% in Tanzania, 9-12% in Kenya) which results in considerable waste of resources and environmental implications.
- Contrary to general belief, charcoal production is not the main cause of deforestation in most cases.

There are three major differences in Brazil with regard to other developing countries:

- Brazil is a highly efficient producer of large-scale industrial charcoal, with biomass-to-charcoal conversion efficiencies ranging from 30 to 35%, particularly from plantations.
- Brazil is the world's largest producer and consumer of industrial charcoal (see Table 2).
- Charcoal production is increasingly becoming a professional activity with most charcoal being produced from dedicated plantations, i. e., in 2000, about 72% of charcoal was produced from

Table 2 - Charcoal production in Brazil, 1990 – 2000 (million m^3)
Quadro 2 – *Produção de carvão no Brasil, 1990-2000 (millhões de m^3)*

Year	Charcoal from native forests	Percentage	Charcoal from plantations	Percentage	Total
1990	24.35	66.1	12.54	34.0	36.90
1991	17.86	57.7	13.10	42.3	30.97
1992	17.82	61.1	11.35	38.9	29.20
1993	17.92	56.5	13.77	43.5	31.70
1994	15.18	46.0	17.82	54.0	33.00
1995	14.92	48.0	16.16	52.0	31.08
1996	7.80	30.0	18.20	70.0	26.00
1997	5.80	25.0	17.80	75.0	23.60
1998	8.60	32.6	17.80	67.4	26.40
1999	8.07	30.0	18.83	70.0	26.90
2000	7.20	28.3	18.20	71.7	25.40

Source: ABRACAVE (2002).

eucalyptus plantations, compared to 34% in 1990 (Abracave, 2002). Approximately 25.4 million m^3 (6.35 Mt) of charcoal were used in 2001 in steel-making, metallurgy, cement, etc.

Currently, traditional charcoal production is primarily from forestry residues resulting from the expansion of agriculture and pasture land, waste from wood processing, sawmills and forest thinning. Traditional charcoal production still represents a major economic activity (primary and secondary) for many rural labourers and small farmers in Brazil, in areas with there is a charcoal making tradition. It is a low prestige and unskilled labour sector that is having a negative effect on the overall performance of this industry.

The future of the charcoal industry is very much intertwined with steel, metallurgy, cement, etc, and thus with the development of these industries; it will also depend on the capacity of the charcoal industry itself to modernize, make better use of by-products, increasing professionalism, etc.

5 Utilization of residues

Residues are a large and under exploited potential energy resource involving many opportunities for better utilization as a large proportion is readily available and represent a good opportunity at low costs. The most important residues are derived from agriculture and forestry, manure, and more controversially, municipal solid waste (MSW).

Residues are currently the main sources of bioenergy and this will continue to be the case in the short to medium terms, with dedicated energy forestry/crops playing an increasing role in the longer term, except in Brazil where plantations already make a significant contribution. The expected increase of bioenergy, particularly in its modern forms, could have a significant impact not only on the energy sector, but also on the drive to modernize agriculture and forestry activities and on rural social development.

5.1 Agriculture

Many attempts have been made to estimate the global energy potential of agricultural residues, but this is a very difficult task and only rough estimates are possible; worldwide, 4 Gt per year may be close to reality. No doubt, large amounts of residues are wasted, or handled inappropriately, causing undesirable environmental and ecological effects.

Sugarcane is one the world's greatest crops, and one of the most promising for energy generation despite the small planted area of approx. 24 Mha (rice and wheat occupy over 200 Mha). This worldwide potential is illustrated in Table 3. Brazil has the world's largest and most efficient sugarcane industry with over 300 Mt of cane milled annually (see Sect 5.3).

Brazil has very large quantities of unused residues, i. e., 250-275 Mt per year,

Table 3 – Estimated worldwide potential from sugarcane residues, 2003
Quadro 3 – *Potencial estimado para resíduos de cana-de-açúcar no mundo, 2003*

Residues	World (million ton)	Brazil (million ton)
Sugarcane production	1,300	338
Bagasse[(1)]	360	100
Trash[(1)] (tops and leaves)	360	100
Total biomass	720	200
Barrels of oil equivalent[(2)]	1,050	280

[(1)] 50% moisture content; [(2)] Higher heating value basis (in thousands).

Source: UNICA, FAO, and COPERSUCAR data[5/].

[5/] Quoted from " A Preliminary Report for the IUPAP Working Group on Energy" by Cerqueira Leite et al (2004) Draft Preliminary Report (forthcoming).

from commercial crops alone, which have not been fully inventoried. It is not possible to provide a detailed account since there is insufficient reliable data on a countrywide basis. Table 4 summarizes potentially recoverable residues from main commercial forestry/crops.

5.2 Forestry

Global recoverable residues from forests have an energy potential of about 35 EJ/year according to (Woods & Hall, 1994); these figures are still valid today. A considerable advantage of these residues is that large amounts are generated by the pulp and paper and saw mill industries, and could be readily available. Currently, most of these residues are utilised to generate energy in these industries, but there is no question that the potential is considerably greater.

One of the difficulties in estimating the potential of residues available for energy use on a national or regional basis, with some degree of accuracy, is the lack of reliable data on total standing biomass, MAI (mean annual increment), plantation density, thinning and pruning practices, current use of residues, etc.

Brazil generates a considerable amount of forest residues (timber, furniture, clearings, pulp and paper, etc). However, no nationwide inventory is available and thus only partial estimates are possible. For example, PAIM (2002) estimates that the forestry sector uses about 166 Mm^3 (c.44.5 Mt) of wood annually, 60% of which comes from plantations.

The pulp and paper industry, with over 1.4 Mha of plantations generates almost 5 Mtoe of residues which are currently largely wasted. For example, ELETROBRAS[5/] has estimated the technical cogeneration potential capacity at 1.7GW in 2003.

[6/] Technical potential is the thermodynamic potential part that can be used.

Table 4 - Brazil- Main commercial crops and residue production only
Quadro 4 *– Brasil – Principais cultivos comerciais e produção de resíduos, somente*

Crops	Planted area (Mha)	Average productivity (ha yr^{-1})	Annual production	Type of residue	Amount of residues (t ha^{-1} yr^{-1})	Total amount of residues (Mt yr^{-1})
Sugarcane*	4.5 to 5	60 to 80 (a)	270-300 Mt	-Bagasse -Barbojo	-20 -20	90-100(b) 90-100
Eucalyptus*	3.0 (c)	30 m^3	90 M m^3	Bark	14,7 (after 7 years)	6.8
Pinus spp. *	1.7	24 m^3	41 M m^3	Bark	18.4 (after 14 years)	2.2
Rice**	3.1	3.2 t	9 Mt	Husks	20%	6.3*** (d)
Maize**	12.3	3.3 t	41.4 Mt	Trash, cobs	2.24	29*** (d)
Soybean**	13.9	2.7 t	37.7 Mt	Straw etc	1.89	26.4*** (d)
Wheat**	1.7	1.9 t	3.2 Mt	Husks	1.33	2.4*** (d)

Notes: Figures in this table are indicative only.

* From Cortez (2002) Personal communication; ** 2001 data from M. Agriculture (www.agricultura.gov.br/spa); *** This is based on a recoverable residue ratio of 0.7 tonne per tonne grain harvested;

(a) Average productivity in the state of Sao Paulo is 79 t ha^{-1} per year; (b) Our estimates are 148-164 Mt, based on a recoverable residue ratio of 0.55 tonne per tonne of harvested cane; (c) Excludes eucalyptus for the production of charcoal; (d) CENBIO estimates are 1.8, 55, 48, and 2.6 Mt, respectively.

Source: See Rosillo-Calle & Moreira (2004).

6 Sugarcane and fuel ethanol sector in Brazil

In 1970, about 50 Mt of sugarcane were produced in Brazil and approximately 5 Mt of sugar. For the 2003/04 harvest (see Table 5) production was 338 Mt of cane, 23.4 Mt of sugar and 14.1 B L^{-1} of ethanol (8.7 B L^{-1} anhydrous, and 5.4 hydrated)[7/]. Major advances have already been made in feedstock production, e.g., in the mid 1980s average productivity of sugarcane was 70 t ha^{-1} yr^{-1} and 66 litres of ethanol tc^{-1}, (4,620 L $ha^{-1}yr^{-1}$), in the central-southern region. In the 2002/03 harvest, productivity reached 90 t ha^{-1} yr^{-1}; 86 L tc^{-1}; (7,740 L h^{-1} yr^{-1}, and in some sites over 8,000 L ha^{-1} have been produced); this represents 30% increase in productivity[8/]. For the 2003/2004 harvest, 149.62 kg of TRS[9/] were produced per t/cane, compared to 146.41 kg in the previous harvest.

The sugar and alcohol industries in Brazil are inextricably interconnected and have faced a major transformation in the past two or so decades, although much more is still needed for their full potential to be achieved, such as modernization of many agronomic practices, technological improvements, greater market-oriented approaches, etc. Sugarcane production demands annual removal of approximately 80 t ha^{-1} stalks, a quantity twenty times greater than that of any of the cereals grown in Brazil.

[7/] See (www.portalunica.com.br/referencia/estadisticas.jsp).

[8/] These figures sometime vary, i.e., other sources give a figure of 6,350 L ha^{-1} yr^{-1}. Sometimes this was due to the way statistics are compiled, i.e., annual or harvesting year.

[9/] Total fermentable sugars. For the 2002/03 harvest cane POL% was 15.11; juice purity 87.7%; cane fibre 12.65.

6.1 Fuel ethanol production

In recent years, a combination of technological, environmental and socio-economic changes are forcing the search for new transportation fuel alternatives. These changes are steadily transforming worldwide markets for new fuels and propulsion systems. For example, acute air quality problems are creating markets for innovative transportation systems in urban areas.

A particular aspect of recent years is the worldwide interest in fuel ethanol as a substitute to petrol in the transportation sector. Already a large number of countries (over 30) have, or are planning to introduce fuel ethanol programmes, i.e., Australia, Canada, Colombia, China, India, Mexico, Thailand, etc.

Demand for ethanol has grown significantly in recent years, as illustrated

Table 5 – Sugarcane & ethanol production data, Brazil 2000/01- 2003/2004
Quadro 5 – *Dados sobre a produção de cana-de-açúcar & etanol, Brasil-2003/2004*

Year	2003/04	2002/03	2001/02	2000/01
Cane (10 Mt)	338.3	318	293	258
Sugar (10 Mt)	23.4	22.5	19.2	16.2
Ethanol (10 B L^{-1})*	14.1	12.7	11.5	10.6
-Anhydrous	8.7	7.0	6.4	5.6
- Hydrous	5.4	5.0	5.1	5.0

* Ethanol has other industrial applications such as fine chemicals, industrial solvents, etc.

Source: UNICA (2004).

in Table 6. Ethanol production surpassed 38 billion per litres (B L^{-1}) in 2003, and could well reach 60 B L^{-1} by the end of the decade. The key players continue to be Brazil and the USA both of which have nationwide programmes. In addition, new and potentially large markets are now emerging, e.g., the EU, China, India and Thailand. Brazil is the world's most efficient ethanol producer, with costs varying from c.US$15cents per litre to US$23cents per litre.

Currently, a major shortcoming is that fuel ethanol is not an internationally commodity, i. e., only just over 3 B L^{-1} yr^{-1} are currently traded, the rest is commercialised internally; this acts as a barrier to further expansion of fuel ethanol programmes since supply remains too inelastic. This will not change significantly until fuel ethanol is not structured, standardised, or commodity exchanged.

7 The Flex Fuel Vehicle (FFVs)

The flex-fuel vehicle is not just an idea it is becoming a major driving force. This concept first developed outside Brazil (USA, Europe, and Japan) as an attempt to find answers to the transportation problem during the late 1980s and 1990s, and is becoming a major driving force in Brazil. For example, in 2003 about 48,000 vehicles were sold as flex-fuel[10]. Table 7 shows the estimated FFV fleet for the year 2010. Some experts estimate this market will reach 50% while others believe that the FFVs could dominate the entire market by around 2010; this is expected to push the demand for fuel ethanol to about 17 billion litres[11].

FFV development could have major implications because of their considerable fuel flexibility. FFV technology allows engines to run equally efficiently on the standard blends of gasoline and anhydrous ethanol, on neat ethanol (hydrous), or any mixture of the two. A key factor of the FFVs is a sensor that can measure on a continuous basis the proportion of fuel in the tank; electronic devices adjust the injectors which supply the fuel on the cylinders for burning, altering the proportion of air present in the combustion in just a few seconds.

[10] See for example Journal Valor Economico, 12-14 March 2004 p.1

[11] See Gazeta Mercantil, 1st March 2004 pB-12.

Table 6 – World ethanol production, 1999 - 2003 (billion litres)*
Quadro 6 – *Produção mundial de etanol, 1999-2003 (bilhões de litros)*

Country/Region	2003	2002	2001	2000	1999
Europe	4.27	4.08	4.03	3.56	3.51
- EU-15	2.37	2.22	2.11	2.07	2.00
America	26.23	23.26	20.68	19.26	20.95
- Brazil	14.07	12.62	11.50	10.61	12.98
- USA	11.18	9.60	8.11	7.60	7.00
Asia	6.65	6.23	6.05	5.90	6.05
Oceania	0.16	0.16	0.18	0.15	0.16
Africa	0.59	0.58	0.55	0.54	0.53
- South Africa	0.40	0.40	0.40	0.40	0.40
World Total	38.3	34.71	31.89	29.81	31.60

* Figures rounded up.

Source: Anon (2003).

Table 7 – Projections for light vehicle fleet in Brazil, 2002-2010
***Quadro 7 –** Projeções para frota de veículos leves no Brasil, 2002-2010*

Year	Gasoline[(1)]	Ethanol[(2)]	Flex-Fuel	Total	Flex-Fuel
	(in millions of vehicles)				(%)
2002	14.68	2.72	0.00	17.41	0
2003	15.41	2.45	0.05	17.91	0.3
2004	16.05	2.15	0.30	18.49	1.6
2005	16.54	1.81	0.75	19.10	3.9
2006	16.73	1.48	1.56	19.77	7.9
2007	16.62	1.18	2.69	20.48	13.1
2008	16.47	0.93	3.86	21.26	18.2
2009	16.30	0.73	5.07	22.09	22.9
2010	16.09	0.56	6.32	22.97	27.5

[(1)] Gasohol blend: 25% anhydrous ethanol and 75% gasoline; [(2)] 100% Hydrous Ethanol.

Source: COPERSUCAR (see footnote5).

The flex-fuel concept is not confined to Brazil; there are many other countries interested in the flex-fuel vehicle because it represents a considerable fuel flexibility improvement. In fact, it is the global interest on fuel ethanol that is stimulating the Brazilian automobile industry's interest in turning the country into a major world producer for FFVs. This could bring major changes both to the fuel ethanol producers and end users. The FFVs present new opportunities because they would enable a more efficient competition with RE and fossil fuel-based cleaner gasoline and diesel[12/].

The FFVs could well represent a new milestone in Brazil and beyond, if implanted in large scale. There are still a few problems to overcome, in particular engine efficiency of blends, since the FFVs are based on a concept different from neat ethanol engine which was designed for optimum performance of hydrous ethanol, i.e., higher compression ratios; likewise, a gasoline engine in Brazil is also designed to run efficiently on standard gasoline-ethanol blends (22-35%). An FFV engine's main priority is to offer greater fuel flexibility, ranging from neat ethanol/gasoline to blends of different proportions. Because of the different characteristics of the fuels, it is difficult to achieve both greater fuel efficiency and flexibility at the same time.

8 Biodiesel in Brazil

Biodiesel use in transport has grown dramatically in the past decade, particularly in the EU, which is leading the world, and in the USA. In the EU, rapeseed and sunflower are the main sources of biodiesel while in the USA the main source is soybean. Brazil has been experimenting with biodiesel for decades, e.g., soy'bean, dende, babaçu, etc. More recently experiments have concentrated in blends both with diesel, ethanol, etc. This is also a reflection of new developments taking place in many other countries, such as in the EU and US.

[12/] This assumption does not take fully into account fossil fuels environmental implications

Biodiesel has been a serious problem in Brazil given the overwhelming dependence of the transportation system on diesel, particularly public transport, which consumes 80% of an annual consumption of approx 36 M m^3. The rest is consumed in electricity generation in remote rural areas. Soybean is of particular interest as Brazil is the world's largest producer and has the capacity to produce over 50 Mt yr^{-1}, and perhaps could produce 1 to 2 M m^3 of biodiesel, under the right conditions.

> Palm oil (dende) has been increasing by available in the international vegetable oil market, and some experts have been comparing it to soybean (capable of 31 Mt/yr by 2010). Brazil offers the world's greatest potential for expanding this crop, mainly because of the availability of productive land. For example, the Federal Government is providing incentives to achieve a minimum annual production of 500,000 tons in the Northern region, under the *PROBIOAMAZON*[13/] programme.

9 Conclusions

Globally, bioenergy has a major role to play; Brazil is in a unique position since the country possesses an enormous biomass resource base and a long historical experience in large industrial scale applications of bioenergy. This potential can largely be enhanced by the combination of increasing productivity and development of new conversion technologies.

Brazil is a major consumer and has a great biomass energy potential which remains largely untapped. There is, for example, a considerable lack of consistent, reliable and up-to-date data on a nationwide scale on its bioenergy potential. This is particularly the case of residues which Brazil produces in large quantities. Despite these difficulties, it is hoped that the *Atlas Brasileiro de Biomassa*[14/] will become, eventually, a truly representative source of biomass energy resources in Brazil. This will help to overcome one of the major constraints for sound decision-making, since the inability to fully address the indigenous biomass resource capability and its likely contribution to energy and development is still a serious constraint to the full realization of bioenergy potential.

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[13/] The main objective of the *PROBIOAMAZON Project* is to help the Brazilian Government initiate a program for the conservation and sustainable use of biodiversity by identifying priority actions; stimulating the development of by projects by facilitating partnerships between the public and private sectors,

[14/] The Atlas of Biomass Energy has been developed by CENBIO. However, given the nature of biomass, considerable more resources are needed to develop a truly nationwide representative biomass atlas.

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