# Brazilian energy matrix and sustainable development

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## 1. Introduction

Brazil is a country of contrasts. Average income and energy consumption statistics hide the fact that there are extremes of wealth and poverty in Brazil. Many districts in the great industrial cities of the South-east are modern and prosperous, comparing favorably with many cities in the industrialized countries. However, there are also very poor urban slums and rural communities, mainly in the North-east. In the 1970s there was a saying that there are two countries in Brazil, "a Belgium inside an India", in which 30 million have a standard of life comparable to urban dwellers in Belgium and the remaining 150 million have one comparable to the peasants in India.

However, Brazil can address its poverty problems if a more equitable distribution of wealth is combined with exploiting the country's extremely favorable conditions for providing energy from renewable sources. Lessons learnt from Brazil's national alcohol program are today a world benchmark for questions on social and environmental sustainability.

## 2. Social and economic issues

Brazil recorded an astonishing economic performance in the 1990s, having managed to survive and grow in spite of several crises affecting countries such as Russia, Indonesia, Malaysia, Korea, Mexico and Argentina. Despite a strong decrease in its growth impetus, the Brazilian GDP nonetheless underwent an increase in 2001 from R$ (réal) 1.09 to 1.184 trillion (US$ 501.694 billion on the basis of an exchange rate of R$ 2.36 to a dollar), a fact that can only be attributed to general price rises. The official inflation indicator (IPCA) in the period showed a 7.67 % increase. The net GDP increase rate was only 1.51 %, considered modest when compared to 4.3 % in 2000. This may be attributable to the American and Argentinian crises. The per capita GDP value showed a similar behavior; in 2001 it amounted to R$ 6,873, which was only 0.19 % above the value for the year 2000, which itself was 2.99 % greater than that of 1999.

Brazil still presents a picture of wide inequality among its various states. Quality-of-life indicators still vary significantly throughout the country. In the 1970s, Brazil used to be dubbed "Belindia" due to its mix of human development levels simultaneously typical of both industrialized OECD countries (like *Bel*gium) and low average income developing ones (like *India).*

This trend is unfortunately confirmed by a comparative analysis of the most recent Human Development Index (HDI) figures [UNDP, 2002], and regional HDI values. Figure 1 presents an HDI ranking for Brazilian states compared to other countries. It is very important to note that though no direct comparison is valid, it is being prsented in order to illustrate local disparities – actual state HDI figures have in fact increased from 1998 to 2002, the year of UNDP's most recent report to date. Therefore, the report is expected to discover that some Brazilian states may have risen to positions even higher than 31st in the HDI ranking. At the same time, there are some other Brazilian states, e.g., Maranhão, Alagoas and Piauí, with HDIs comparable to those of Cambodia or Papua New Guinea.

The quality of life varies widely throughout the different Brazilian regions. Also, Brazil displays very different consumption patterns because it is a large equatorial country, rich in natural resources. As Brazil has practically no coal reserves, fuelwood is the main energy source still being used mostly for cooking by low-income families. As the living conditions of these communities gradually improve, there is a shift in their energy use from fuelwood towards other sources, such as electricity, LPG (liquefied petroleum gas) and other petroleum derivatives. In a further step, modern biomass has an important role to play in this development towards a more sustainable energy use pattern.

## 3. The Brazilian energy matrix

By North American standards, Brazil in 2002 is still a modest consumer of energy. The total electricity consumption per capita in 2000 was about 14% and total primary energy supply per capita was 13% of that of the US [IEA, 2002]. The Brazilian population of 170 million people is 62% of that of the US. National reserves are presented in Table 1.

The following items characterize production and use.

*Petroleum.* Indigenous production was a major issue during the 1970s oil crisis. In the period 1979-2000, total oil reserves increased significantly (more than 10 times). In 2001, indigenous production accounted for 177,000 tonnes (t) per day (1.3 million barrels per day; 1 barrel = 0.1364 t). Production has been increasing during the last 10 years at a rate of 8.2 %/yr, ranking Brazil 18th in the world. But new records in production are not being matched by increasing volumes of reserves. Thus, the reserves/annual production ratio has decreased over the years, to 17.4 years in 2001. Most of the production (83.4 %, exclusive of liquified natural gas or LNG) was extracted from offshore fields.

*Natural gas.* There was an 8.0 % yearly growth in indigenous production during 1992-2001, reaching 14 billion $m^3$ in 2001, including reinjected gas volumes. Brazil in 2001 was the 37th largest producer of natural gas in

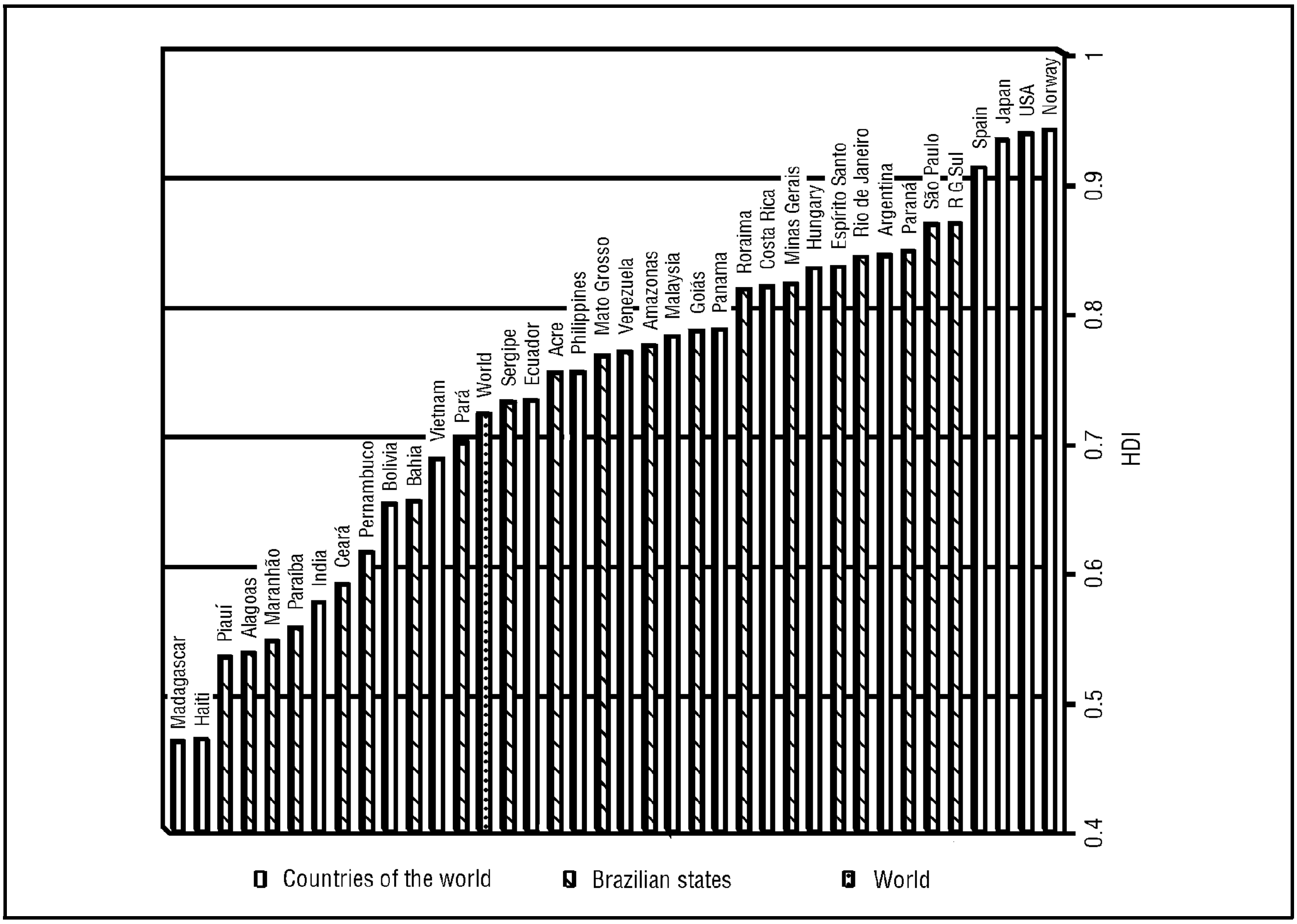


Figure 1. Human development index (HDI) values of Brazilian states (base year 1998)[1] compared to some country 2001 values[2]

Sources: 1. SEADE, 2000; 2. UNDP, 2002

**Table 1. Brazilian energy resources and reserves[1]**

| Sources | Unit | 1979 | | | 2000 | | |
|---|---|---|---|---|---|---|---|
| | | Measured | Inferred / estimated | Total | Measured | Inferred / estimated | Total |
| Petroleum | Thousand $m^3$ | 198,000 | - | 198,000 | 1,296,273 | 977,427 | 2,273,700 |
| Natural Gas | Million $m^3$ | 47,000 | - | 47,000 | 231,233 | 172,637 | 403,870 |
| Coal | Million tonnes | 4,836 | 17,938 | 22,734 | 10,131 | 222,390 | 32,370 |
| Shale oil | Thousand $m^3$ | 465,000 | 207,000 | 672,000 | 445,000 | 9,402,000 | 9,847,100 |
| Nuclear - U3O8 | Tonnes U3O8 | 126,000 | 89,300 | 215,300 | 177,500 | 131,870 | 309,370 |
| Hydrolectric | GW year[2] | 67.0 | 39.5 | 106.5 | 92.9 | 50.5 | 143.4 |

**Notes**

1. Not including other renewable energy resources
2. Firm energy

Source: MME, 2001

the world. Proven reserve volumes did not keep pace with production, reserves/annual production declining 0.5 % in 2001 to 15.7 years. Offshore fields accounted for 58.2 % of national NG production in 2001. 2.6 billion $m^3$ were burnt and lost and 3.0 billion $m^3$ reinjected (21.6 %). Brazil is developing a vigorous program to import NG from Argentina and Bolivia, aiming at an increase in the energy use share from 2 % in 1999 to 12 % in 2010. From Bolivia alone, agreements were reached to undertake or contract for the supply of 30 million $m^3$/day, with possible expansion to 50 million $m^3$/day.

*Coal* is not abundant in Brazil; it is found in significant quantities only in the southern states. Basically all indigenous coal is bituminous. Pre-washed coal has an ash content higher than 40 % and can be used only for non-metallurgical purposes such as steam production.

*Nuclear:* In Brazil, this segment from two power plants only amounts to 1.3 % of the total consumption. Brazil

**Table 2. Hydroelectric resources in GW of installed or installable capacity**

| Region | 1980 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| North | 4.073 | 4.281 | 4.281 | 5.131 | 6.256 | 7.381 | 8.506 |
| North-east | 8.217 | 10.136 | 10.136 | 10.136 | 10.586 | 10.586 | 10.586 |
| South-east | 25.095 | 29.291 | 30.008 | 30.882 | 32.139 | 33.913 | 34.132 |
| South | 13.400 | 15.774 | 16.159 | 16.582 | 17.387 | 18.207 | 18.207 |
| Total | 50.705 | 59.482 | 60.584 | 62.731 | 66.368 | 70.087 | 71.431 |

Source: ONS, 2002.

has been endowed with the sixth largest uranium reserves in the world (about 300,000 t), but its economic feasibility has not yet been assessed. It is still an importer of enriched uranium. Enrichment technology has been partially mastered in the country, although at laboratory scale, producing fuel elements for use in experimental reactors. There is presently no domestic production of enriched uranium. Besides high production costs, the shutdown of Germany's nuclear program may adversely affect Brazil through decreased spare part availability.

*Hydroelectricity:* The country is well endowed with hydroelectric resources, which are spread out over the country with a concentration in the South-east. This potential is evaluated in such a way as to produce an average power level that is guaranteed. The installed capacity of 79,000 MW of Brazil's immense power sector stimulates increased consumption of electricity from this source. Brazil is an important partner in the international Itaipu power plant, the largest in the world, currently with a 12,500 MW capacity (to be further expanded to 14,000), as well as 22 other plants with capacities equal to or above the 1000-MW potential. In the year 2000, Brazil's electric energy consumer market estimates were of 48 million consumers, amounting to 305.6 TWh in that year. Consumption projections for the period 2000-2010 are that the consumption may reach the 589.6 TWh level, or an average yearly increase of 5.9 % The country's demand is dealt with by a 67,700 MW capacity; 59,900 of this is of hydro origin and 7,900 from thermal plants. The electricity industry's planning sectors are estimating the need for investments around US$ 23 billion (involving generation, transmission and distribution infrastructure) in order to be able to cope with the fast-growing demand. In December 1998 the two electricity transmission systems were interconnected by 1,227 km of 500 kV lines, with planned doubling of capacity by April 2003, to help tackle electricity shortage problems during dry seasons. Hydroelectric resources are shown in Table 2.

*Firewood:* Charcoal and firewood were the predominant fuels in Brazil until 1954; but since then their use has remained approximately constant, although this means that in relative terms, their contribution has decreased rapidly. Firewood consumption in 1979 was 87.5 million t (Mt) (220 milllion m$^3$ of wood, at 10 % humidity) (energy equivalent 920 PJ). The 2001 consumption figure was 44.6 Mt (470 PJ). Firewood consumption by end-use is shown in Table 3.

*Charcoal:* Consumption in 1979 was 16.7 million m$^3$, corresponding to 133 PJ; consumption in 2001 was 25.5 million m$^3$ (202 PJ). In Brazil charcoal is an important raw material for the production of pig-iron, and about 40 % of Brazil's steel production makes use of charcoal instead of imported coke. It has traditionally been produced from natural forests, a process that has resulted in deforestation in many areas. In addition to its detrimental environmental effects, this has led to shortages in firewood supply and price increases, since firewood and charcoal had to be brought up from ever greater distances. Since Brazil is going through a process of rapid urbanization, the consumption of wood for domestic purposes (mainly cooking) has been declining and it is being replaced by LPG and electricity. However, the substitution of fuel oil in boilers has increased wood consumption for industrial purposes. Sustainable forests met 54% of the charcoal demand in 2001 [Brito, 1997].

**Table 3. Firewood use in Brazil**

| End use | 1976 ($10^6$ t) | 2000 ($10^6$ t) |
|---|---|---|
| Residential | 52 | 21.4 |
| Commerce, transportation | 1 | 0.3 |
| Industrial | 13 | 17.5 |
| Farming | 14 | 5.4 |
| Total | 88 | 44.6 |

Source: MME, 2001

*Biomass:* Brazil is a large tropical country with high potential for biomass. Agricultural use of land could be increased from 42 million ha (Mha) in 2000 to 220 Mha, without additional unsustainable deforestation. Besides traditional fuelwood-burning, the main modern sources are sugarcane products (ethanol and bagasse) and reafforestation wood. With the alcohol program, started in 1975 with 0.9 billion liters (Gl), the participation of biomass in the Brazilian energy matrix has reached 19 % in 2000, corresponding mainly to 14 Gl of ethanol produced from sugarcane. The use of bagasse as an energy source in alcohol distilleries yields a considerable energy surplus, now sold with government incentives for the purchase of this electricity surplus. Sugarcane products accounted for 875 PJ in that year. Traditional firewood use, basically residential, has declined significantly over the last few decades, substituted by more efficient fuels and end-use technologies. Government subsidies have helped reafforestation of 5.5 Mha in 2001 (compared to 3.3 Mha in the 1965-1980 period) to produce charcoal, fuelwood, pulp, and paper.

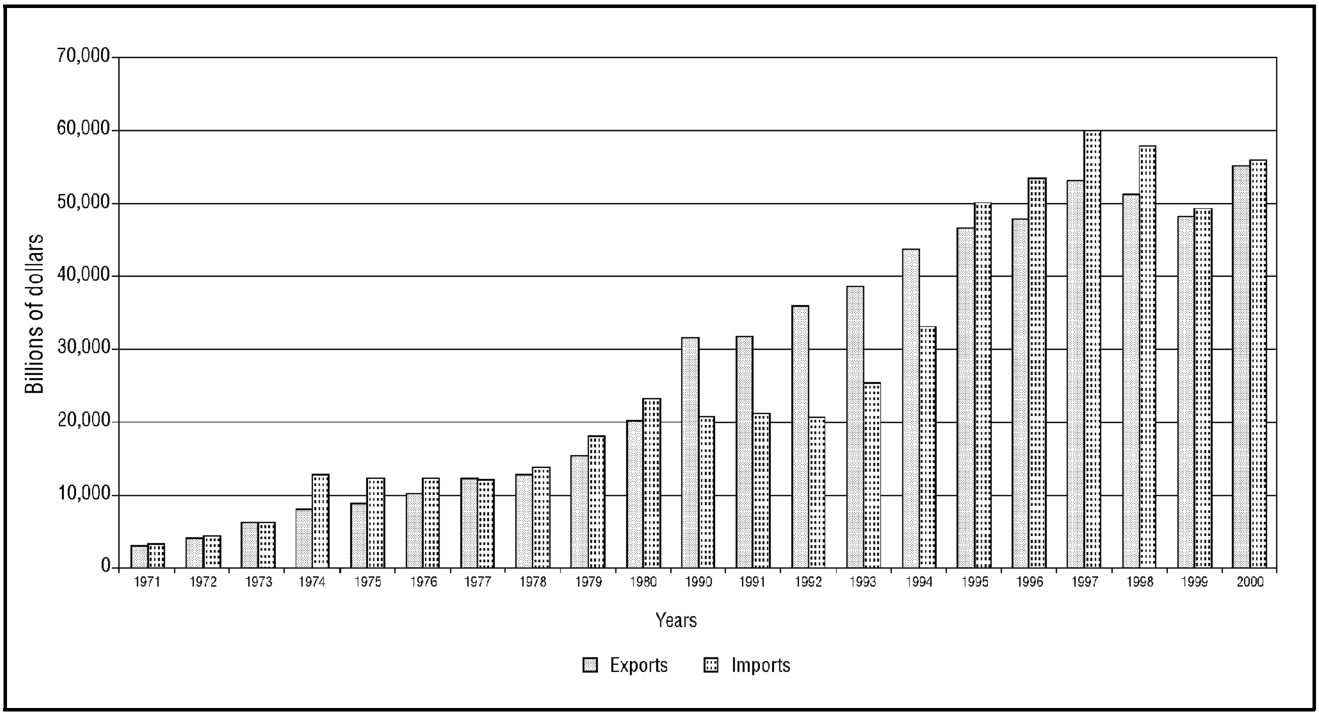


Figure 2. Oil exports and imports

Source: Brazilian Energy Balance 2001

**Table 4. Brazilian energy consumption by source in 2000**

| Energy sources | Unit | 1979 | | 2000 | | Average yearly rate of growth 1979-2000 |
|---|---|---|---|---|---|---|
| | | Quantity | % | Quantity | % | |
| Petroleum | PJ | 2150 | 40.7 | 3631 | 37.50 | 4.88 |
| Natural gas | PJ | 22 | 0.4 | 318 | 3.28 | 27.31 |
| Alcohol | PJ | 840 | 1.6 | 233 | 2.41 | 9.73 |
| Hydrolectricity | PJ | 1514 | 28.3 | 3997 | 41.28 | 9.22 |
| Coal | PJ | 230 | 4.3 | 114 | 1.18 | -6.16 |
| Sugarcane bagasse | PJ | 246 | 4.7 | 598 | 6.18 | 8.42 |
| Charcoal | PJ | 133 | 2.6 | 179 | 1.85 | 2.72 |
| Woodfuel | PJ | 917 | 17.4 | 612 | 6.32 | -3.62 |
| Total | | 5277 | 100 | 10257 | 100 | 5.64 |

Source: MME, 2001

Energy consumption in Brazil grew at a very high rate of 5.6 %/yr from 1979 to 2000. In the hydroelectric sector growth has reached 9.22 %/yr. Natural gas growth is significant (27.3 %/yr), but this huge growth trend is expected to decline. The evolution of primary energy shows a very rapid shift from "traditional" to "modern" fuels during this period. Biomass use has decreased, but has also shifted to modern uses, mostly from fuelwood combustion to sugarcane products. Energy consumption by source is shown in Table 4.

## 4. Issues and policies

The consequences of the dependence on oil imports on the Brazilian balance of payments have become disastrous since 1974. Such imports corresponded to 9.4 % of the value of exports in 1972, but increased to 51.2 % by 1980. Although a successful effort was made to increase exports, as shown in Figure 2, it was not enough to balance trade deficits. This was the main reason for the introduction in 1975-1980 of the alcohol program, which, together with increased internal oil production and decreased international oil prices, lowered the percentage to 13.7 % in 1990, 6.9 % in 1998 and 11.8 % in 2000.

A deficit of US$ 8 billion in two years in 1974 and 1975, together with rising oil prices and increased dependence on imports, led the government to swift action. In 1974 the price of sugar in the international market was very low (200 US$/t). Benefiting from government subsidies, the program boomed. All gasoline used in the country was rapidly converted to "gasohol", a blend with up to 26 % alcohol. In 1979, the Iraq-Iran war threatened the stability of oil supplies from the Middle East, and the

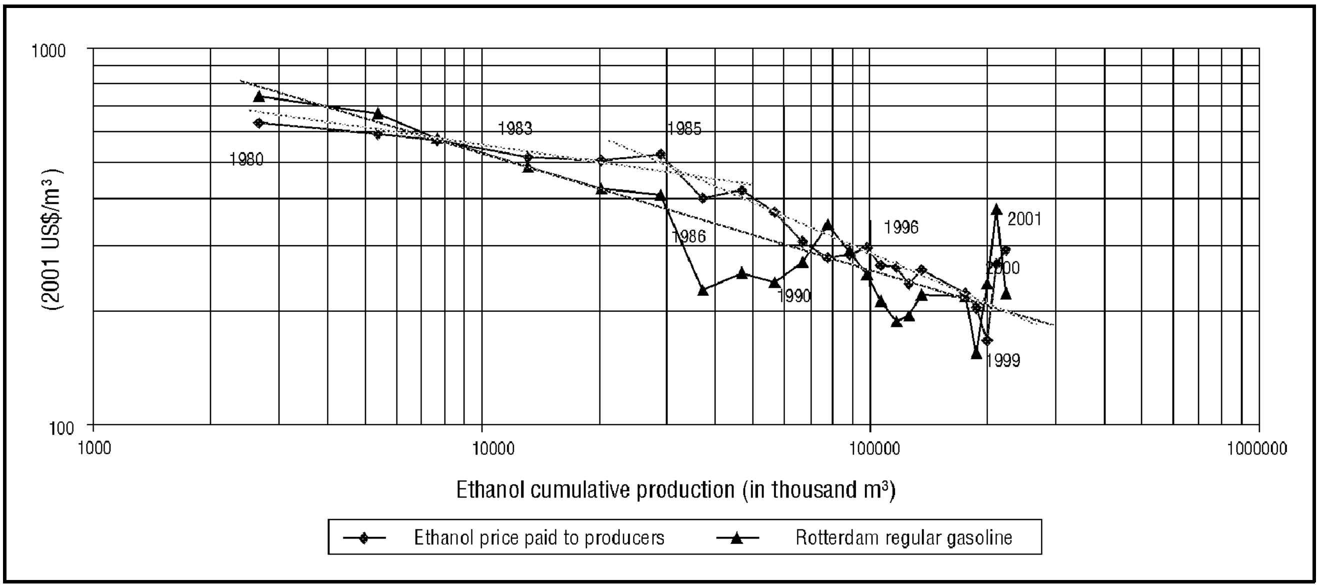


Figure 3. Ethanol learning curve

Source: CENBIO, 2002

automobile manufacturers, encouraged by the government, took the bold position of producing cars with new engines adapted for pure alcohol consumption. Brazilian production of alcohol reached a total of 10.7 Gl in 2001, 30 % of which was consumed as hydrated alcohol (4 % water) in more than 6 million vehicles.

Notwithstanding the decreased production of dedicated alcohol-fuelled cars due to lower international oil prices, the use of ethanol as a lead-free fuel has increased consistently. Today, renewable energy from biomass is regaining strength because of factors such as dependence on external sources for fossil fuels, currency devaluations, political problems in oil-producing companies, environmental restrictions to air pollution, climate change issues and increased public awareness of a broader concept of sustainable development. The latter includes job creation and energy integration of isolated communities.

The Brazilian alcohol program is now a paradigm to be followed. Subsidies applied to this renewable energy technology during its infancy are crucial to provide conditions to compete in the fossil fuel market. After maturation, these incentives must be phased out by political sunset clauses. As shown in the learning curve (Figure 3), costs decay as accumulated sales volumes rise.

This benchmark is now being applied throughout the world to a wide range of innovative technologies. While fossil fuel use grows at a rate of 2 % per year, wind energy and solar photovoltaics grow at 30 %/yr, solar heating at 8 %/yr, small hydro and biomass at 3 %/yr each.

On the basis of this experience, Brazil has proposed very recently at the Johannesburg 2002 World Summit on Sustainable Development (WSSD) an initiative [WSSD, 2002] aiming at the establishment of concrete global targets and time-frames of minimum shares of energy from renewable sources, allowing non-compliant developed countries to purchase energy produced by the developing ones. It was a way of achieving the Millenium Goals for poverty alleviation and eradication of social exclusion, extensively publicized by the world media and hugely supported by environmentalists and general public opinion. Despite the strong opposition from some developed countries which are unwilling to modify their consumption patterns (such as the US and Japan) and oil producers (Nigeria and Middle Eastern OPEC countries), many other countries (such as those in Latin America and the Caribbean, the European Union, Norway and New Zealand) are now defining a common ground for cross-regional targets.

## 5. Conclusion

Although Brazil still suffers from severe social disparities, the country's learning experience on renewable sources of energy is a way of achieving sustainable development by using market forces. Compulsory targets and subsidies to infant new technologies to generate a large demand are important policies for changing the current and unsustainable world energy matrix towards a cleaner and more socially equitable pattern of energy production. ■

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