UNIVERSIDADE FEDERAL
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INSTITUTO DE ECONOMIA

# Energy as determinant of climate measures: the case of Brazil

nº 377

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Textos para Discussão

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# ASSETS

Since the 1980's, concern with potencial climate changes as result of greenhouse gases (GHG) emissions is growing. The creation of the International Panel on Climate Change (IPCC) in 1988 was a response to this concern while the United Nations Framework Convention on Climate Change (FCCC) is the first cooperative global attempt to address this issue. Many countries signed the FCCC agreement that, among other items, requires OECD countries to reduce their GHG to the leves of 1990 by the year 2000 and to provide assistance for developing countries to enhance their ability to minimize GHG emissions as well.

This report highlights the difficulties that Brazil is facing to achieve the ultimate goal of reducing GHG emissions. Our aim is to improve the understanding of the economic driving forces that are pushing GHG emissions up in the Brazilian energy sector despite government commitment to mitigate environmental impacts of energy supply and consumption. Our report reviews the long term trends of Brazilian energy supply and demand, and it estimates the related ghg emissions. The main driving forces of the energy sector (population growth and urbanization; industrialization and economic groth; energy policy; instiyutional arrangements and pricing) and the options for mitigating $CO_2$ emissions are analysed.

## 1 - Introduction

Since the 1980's, concern with potential climate changes as result of greenhouse gases (GHG) emissions is growing. The creation of the International Panel on Climate Change (IPCC) in 1988 was a response to this concern while the United Nations Framework Convention on Climate Change (FCCC) is the first cooperative global attempt to address this issue[1]. Many countries signed the FCCC agreement that, among other items, requires OECD countries to reduce their GHG to the levels of 1990 by the year 2000 and to provide assistance for developing countries to enhance their ability to minimize GHG emissions as well.

This report intends to highlight the difficulties that Brazil is facing to achieve the ultimate goal of reducing GHG emissions[2]. It is assumed that response to this issue will remain largely determined by energy policies and that GHG emissions are not the main foundation for energy policy. Our aim is to improve the understanding of the economic driving forces that are pushing GHG emissions up in the Brazilian energy sector despite government commitment to mitigate environmental impacts of energy supply and consumption.

The next section of our report reviews the long term trends of Brazilian energy supply and demand, and it estimates the related GHG emissions. Section three studies the main driving forces of the energy sector: population growth and urbanization; industrialization and economic growth; energy policy; institutional arrangements and pricing. Section four review the options for mitigating $CO_2$ emissions, pointing out opportunities and identifying economic hurdles.

## 2 - Energy Demand and Carbon Emissions in Brazil

Before 1950, energy consumption in Brazil was mainly supplied with traditional energy sources (firewood) but it changed substantially ever since then. Industrialization, population growth, and urbanization were the driving forces of this change. Import substitution industrialization policies (Tavares, 1979) stimulated the widespread of energy-intensive consumer goods (cars, electric appliances etc), and this was accompanied by a rapid growth of population and an intensive urbanization process. Indeed, the Brazilian population increased from 51,9 millions in-habitants in 1950 to 95,8 millions in 1970s, while the share of urban population augmented from 36.2% to 55.9%, in the same period. This rapid process of industrialization, population growth and urbanization induced a very substantial increase in energy consumption, specially oil products and electricity (table 1).

Table 1
Total Primary Energy Demand
(Millions of Toe)

| | 1955 * | | 1970 | | 1980 | | 1990 | |
|---|---|---|---|---|---|---|---|---|
| Oil Products | 9.70 | 37% | 25.06 | 34% | 54.31 | 39% | 59.38 | 32% |
| Electricity | 0.80 | 3% | 11.54 | 15% | 37.38 | 27% | 59.94 | 33% |
| Natural Gas | - | - | 0.16 | 0.2% | 1.07 | 0.7% | 4.10 | 2.2% |
| Sugar cane products | 1.87 | 7% | 3.53 | 4,8% | 9.08 | 6.3% | 17.93 | 10% |
| Coal | 1.70 | 6% | 2.33 | 3% | 5.20 | 4% | 9.40 | 5% |
| Traditional | 12.43 | 47% | 32.00 | 43% | 31.60 | 23% | 30.30 | 17% |
| Total Demand | 26.50 | 100% | 74.62 | 100% | 138.64 | 100% | 183.05 | 100% |

Sources: MME (1994) and Boa Nova (1985)

In the post war period, the main objective of the Brazilian energy policy was to promote domestic supply of energy to induce industrialization (de Oliveira, 1977). Several state-owned electric power utilities were incorporated to develop hydropower resources in different regions of the country, and a national oil company (Petrobrás) was created to exploit domestic oil resources and develop oil refining as well. Efforts were made to promote domestic production of coal but the poor quality of domestic coal restrained the role of its supply.

At the beginning of the 1970's, hydropower was the main primary energy source used to generate electricity while imported oil was the chief source of fuels supply[3]. Imported coal was used almost exclusively in the steel industry that was a large user of charcoal as well. Firewood was extensively used in rural areas for cooking.

The oil crisis induced a major change in the Brazilian energy policy. Oil was the only large Brazilian import. The oil price escalation produced a very substantial deficit in the trade balance that became a major macroeconomic barrier to economic growth. The reduction of energy dependence was then an energy policy priority.

Programs with the intent of substituting imported oil for domestic energy sources were launched. Petrobrás started to develop off-shore oil fields to increase domestic production and eventually natural gas as well. Electricity use, including thermal uses[4], was intensively promoted and domestic coal was subsidized. The use of biomass was stimulated: the alcohol program was launched and charcoal was subsidized. Cooperation with Germany to develop a domestic nuclear power industry began as well. At the end of the 1970's, an energy conservation program was initiated but its main objective was in fact the substitution of imported oil (Araújo & ali, 1993).

Between 1970 and 1990, industrialization, urbanization and population growth remained the main determinants of energy consumption. From the supply side, the impact of the new energy policy was immense however (table 1). The use of modern fuels spread to rural areas, reducing the role of traditional fuels in the Brazilian energy balance. Domestic production of oil increased substantially, rapidly reducing the Brazilian dependence of oil imports. Natural gas and alcohol started to permeate the energy balance while the share of electricity in the total energy consumption increased rapidly. It is interesting to remark that despite the rapid decrease of firewood use, the share of renewable energy sources remained considerably high in the Brazilian economy (60%) as compared to international average (about 23 percent - CEPEL, 1994).

More recently, the Brazilian energy policy started to change again. Several factors are reducing the scope for renewables in the Brazilian energy balance. First, oil price is expected to remain relatively low, reducing the competitiveness of alternative energy sources. Second, large oil resources were discovered off-shore, suggesting that domestic production can supply liquid fuels demand. Third, natural gas production is growing while imports from Bolivia and Argentina are currently under negotiations. Moreover, recent trends indicate that the alcohol share in total energy consumption is diminishing and that the hydropower share is likely to reduce in the near future as well.

Indeed, to substitute imported oil is no longer the core of the Brazilian energy policy. At the beginning of the 1990's, a comprehensive review of economic policy induced the Brazilian government to abandon import substitution policies. Ever since, the Brazilian economy is being progressively opened to foreign trade and investments.

This new economic policy is completely reshaping the long standing institutional arrangements of the energy sector. Chief amongst these changes is the privatization process that is reducing the role of state-owned companies in the energy scene. It is too soon to assess the full impact of privatization on the energy balance but there are reliable signs that discount rates will be substantially higher. This is expected to reduce the economic attractiveness of long lead time projects such as renewable energy sources.

In 1993, energy consumption in Brazil summed up to 182.7 MToe (table 2), of which 33 percent was fossil fuel, 36 percent hydropower[5] and 22 percent biomass. The two main components of biomass are firewood and sugar-cane products. Manufacturing and transportation are the largest consumers of final energy sources. Liquid fuels are mainly used in transportation while solid fuels and gases are mostly used in manufacturing. Manufacturing uses a diversified mix of energy sources, while transportation is a user of liquid fuels (oil products and alcohol). Traditional fuels are chiefly used in the residential sector; nevertheless, there is a very substantial use of traditional fuels (mainly charcoal, in the steel industry) in manufacturing as well.

Table 2
Energy Balance Brazil - 1993
(millions of toe)

| | oil products | solid fuels | electri-city | Gases | Traditional | sugar cane products | *Total Energy Requirement* |
|---|---|---|---|---|---|---|---|
| Production | 32.46 | 1.78 | 68.08 | 7.12 | 28.24 | 18.97 | **156.65** |
| net imports | 30.40 | 8.85 | 8.00 | 0 | 0 | 0.79 | **48.04** |
| total final consumption | 60.15 | 7.12 | 69.86 | 5.04 | 21.66 | 18.84 | **182.67** |
| * energy sector | 3.45 | 0 | 2.30 | 1.32 | 0 | 0 | **7.07** |
| * residential | 5.39 | 0 | 15.58 | 0.12 | 8.38 | 0 | **29.47** |
| * services | 0.81 | 0 | 13.92 | 0.06 | 0.16 | 0 | **14.95** |
| * transportation | 28.77 | 0 | 0.34 | 0 | 0 | 6.06 | **35.17** |
| * primary | 3.75 | 0 | 2.33 | 0 | 1.85 | 0 | **7.93** |
| * manufacturing sector | 17.98 | 7.12 | 35.39 | 3.54 | 11.25 | 6.03 | **81.31** |

Source: MME (1994)

Notes:-The difference between "production plus net imports" and "total final consumption" is due to the losses in transformation and distribution.

- total energy requirement comprises primary and secondary energy
- primary sector comprises agriculture, and cattle raising
- Oil Products comprises, gasoline, kerosene, diesel oil , naphta, LPG and fuel oil
- traditional comprises firewood, and others

## 2.1 - Carbon Emissions: Recent Trends

There are several studies assessing carbon emissions of the Brazilian energy sector. These studies use the national energy balance data and specific carbon emission technical coefficients to estimate emissions. In the case of fossil fuels, generally the same coefficients adopted by OECD countries are used while in the case of renewable energy sources (hydropower, sugar-cane and planted forests) it is assumed that there are no emissions.

Tables 3 and 4 present estimates of carbon emissions of the Brazilian energy sector in 1970 and 1990. As expected, as far as green house gases are concerned, transportation and manufacturing are the most environmentally aggressive sectors of the Brazilian economy. Although manufacturing consumes twice as much energy as compared to transportation, their carbon emissions are very similar. This situation is due to the high share of renewable energy sources used in industry (nearly 55%); energy consumption in transportation is highly concentrated on oil products (82,8%).

Table 3
Carbon Emissions by Source of Energy and by Consuming Sector - 1970
Millions of tons of Carbon (MT - C)

| Sector | Oil | Natural Gas | Coal | Charcoal | Sector subtotal | Firewood | Sector total | % Sector |
|---|---|---|---|---|---|---|---|---|
| Transformation* | 0.60 | 0 | 0.62 | 0 | **1.22** | 0.65 | **1.87** | 4,8 |
| Energy** | 0.99 | 0.10 | 0 | 0 | **1.09** | 0 | **1.09** | 2,8 |
| Residential | 1.53 | 0.07 | 0 | 0.53 | **2.13** | 4.43 | **6.57** | 16,7 |
| Commercial and Public | 0.23 | 0 | 0 | 0.04 | **0.27** | 0.24 | **0.51** | 1,3 |
| Agriculture and cattle raising | 0.35 | 0 | 0 | 0.02 | **0.38** | 5.70 | **6.08** | 15,5 |
| Transport | 11.41 | 0 | 0.02 | 0 | **11.43** | 0.05 | **11.48** | 29,2 |
| Industrial | 5.00 | 0.12 | 1.43 | 1.33 | **7.89** | 3.83 | **11.72** | 29,8 |
| Total | 20.14 | 0.29 | 2.07 | 1.92 | **24.42** | 14.91 | **39.33** | 100 |

Source: SANTOS (1993)
Note: * Emissions as a result of energy transformation (ex. refineries, charcoal production).
** Emissions as a result of **energy consumption** in energy industries.

The energy sources that most contribute to carbon emissions are, respectively, oil and firewood (from native forests). However, the emissions trend by source of energy shows that the rate of growth of oil product and firewood emissions is much lower than emissions from others sources. In fact, firewood emissions decreased 20% between 1970 and 1990. Natural gas is the energy source that had the largest increase in emissions (833%) in that period, as result of a substantial increase in its consumption. However, natural gas has actually contributed toward a lower overall rate of growth of $CO_2$ emissions since it substitutes oil products that have a much higher rate of $CO_2$ emission.

Table 4
Carbon Emissions by Source of Energy and by Consuming Sector - 1990
(MT-C)

| Sector | Oil products | Natural Gas | Coal | Charcoal | Sector subtotal | Firewood | Sector total | % Sector |
|---|---|---|---|---|---|---|---|---|
| Transformation | 0.05 | 0 | 1.56 | - | 1.61 | 2.50 | 4.11 | 5,6 |
| Energy | 2.97 | 0.78 | 0 | 0 | 3.75 | 0 | 3.75 | 5,1 |
| Residential | 4.58 | 0.10 | 0 | 0.77 | 5.45 | 1.85 | 7.30 | 10 |
| Commercial and Public | 0.53 | 0 | 0 | 0 | 0.60 | 0.13 | 0.74 | 1 |
| Agriculture and cattle raising | 2.86 | 0 | 0 | 0 | 2.87 | 2.52 | 5.39 | 7,4 |
| Transport | 2.41 | 0 | | 0 | 24.14 | 0 | 24.14 | 32,9 |
| Industrial | 7.21 | 1.81 | 7.02 | 6.75 | 22.81 | 5.01 | 27.83 | 38 |
| Total | 42.35 | 2.70 | 8.59 | 7.61 | 61.27 | 12.02 | 73.30 | 100 |

Source: SANTOS (1993)

Firewood emissions data have to be used carefully. First, data concerning firewood consumption are not reliable since they consist of rough estimates with no empirical data collection to support these estimates. Second, firewood emissions were estimated assuming that 80% of firewood used in the residential sector (for cooking) come from selective collecting and 20% of firewood used in industry come from planted forests, both with null net emissions. Once again, there is no empirical support for these estimates. Moreover, the fact that firewood consumption devreased does not necessarily mean that the burning of firewood was reduced. Indeed, slash-and-burn technique is still largely used by rural migrants (mainly in the Amazon Region). Therefore, although firewood consumption for cooking reduced, large amounts of firewood are still burning in rural areas.

Table 5 shows a remarkable increase of $CO_2$ emissions between 1970 and 1980. During this period, the Brazilian economy had a very vigorous GDP growth (8.6% yearly), inducing a substantial increase in energy consumption, especially in transportation and industry. However, carbon emissions increased at a lower rate than the energy consumption. In the 1980's, the growth of energy consumption was much smaller, partially due to poor economic performance (GDP was only 1.5% a year in that period) but once again, the growth of emissions was far below the growth in energy consumption. This data confirms the widespread view among Brazilian policy-makers that the Brazilian economy is becoming more environmentally friendly.

Table 5
Trends of Primary Energy Demand and $CO_2$ Emissions in Brazil

| Year | GDP US$Billion | growth % | Energy MToe | growth % | Emissions Mt-C | growth % |
|---|---|---|---|---|---|---|
| 1970 | 84.0 | - | 74.5 | - | 39.3 | - |
| 1980 | 193.0 | 129.8 | 139.3 | 86.9 | 66.7 | 69.7 |
| 1990 | 223.1 | 15.6 | 181.2 | 30.1 | 73.3 | 9.9 |

Source: MME (1994) and Santos (1993).

However, the reduction in $CO_2$ emissions was largely the result of energy substitution (biomass for oil products, and LPG for firewood) and electrification, using hydropower, of the Brazilian economy. It is important to note that oil substitution was mainly induced by policies that are no longer in place. Indeed, the new context is threatening the future of renewables (alcohol and hydropower) in the energy balance. Therefore, future trends have to be analyzed carefully since it seems they are likely to be quite different from the recent past ones.

## 2.2. Future Trends of Energy Use and Emissions

The rate of population growth decreased remarkably from 3% a year in the 1960's to approximately 1.3% today (IBGE, 1994). This dramatic shift is the result of profound social and cultural changes induced by industrialization and urbanization. It is expected that the Brazilian population will stabilize at 285 million inhabitants by 2050 (World Bank, 1994).

There was a very substantial slow-down in the process of urbanization as well. Currently, 78% of the Brazilian population is already living in urban areas as compared to 44% in the 1970's. It is expected that the share of the population living in urban areas will stabilize around 85%.

After the oil crisis, the import substitution industrialization policy was oriented to domestic production of energy intensive materials (such as aluminum, steel, paper and pulp, petrochemicals), inducing a rapid increase in the energy intensiveness of the Brazilian GDP. However, it is widely accepted among Brazilian policy-makers that the Brazilian industrial sector is mature and there is no need to induce substantial changes in the structure of the industrial sector in the future. Therefore, it is expected that the energy intensity of the GDP will stabilize.

Despite these auspicious trends, energy consumption is estimated to keep growing still at relatively high rates. Indeed, a very large share of the Brazilian population has not yet access to the benefits of industrialization. The spread of energy intensive household appliances is still very limited;

moreover, the infrastructure needed to support economic development is not fully in place yet. It is expected that these appliances will be largely diffused as income increases. Therefore, energy consumption shall grow substantially and, consequently, carbon emissions will inevitably increase in the near future. However, the pattern of increase of GHG emissions depends on the energy mix that will be chosen to supply energy demand.

The 2015 Plan (Eletrobrás, 1994) estimates that electricity consumption will increase at relatively high rates in the next 20 years. GDP is expected to grow at 5% a year and the rate of yearly increase of electricity consumption is expected to remain between 4.0% and 5.6%. Roughly 22 GW of new generating capacity are needed to match electricity demand to the year 2015. There are 80 GW of hydropotential to be explored as yet but 69% of the remaining hydropotential is located in Amazonia where environmental costs are large indeed. Although the 2015 plan forecasts a gradual increase of thermal power generation[6], Eletrobrás plans to supply most of the increase in electricity demand from hydropower projects.

For the oil sector, Petrobrás estimated oil products future consumption according to different economic growth scenarios. The elasticity of the oil products consumption to GDP was estimated between 0,81 and 0,86 in the period 1994-2005. In the optimistic scenario (annual GDP growth of 6%) oil products consumption would increase 4,9% annually to 2 millions barrels/day in 2005. In the pessimistic scenario (3% GDP growth), oil products demand would reach 1,75 millions barrels/day in 2005.

Santos (1993) assessed a business as usual scenario for energy consumption, assuming that **no restrictions will be introduced to limit carbon emissions** and that the Brazilian economy will grow in average at 5% over the period 1995-2025. This scenario introduces no change in energy efficiency, reduces the share of biomass in the energy mix and assumes that electricity will remain essentially generated from hydropower until the complete exploitation of the large Brazilian hydropotential. This is a conservative assumption since the privatization of electricity supply industry (ESI) is likely to reduce the role of hydropower in Brazilian electricity supply. This scenario progressively reduces the production of alcohol cars and the share of anhydrous alcohol mixed with gasoline is reduced from 22% to 10%[7] as well. Moreover, the share of steel production made using charcoal is reduced from 20% to 10% and the share of firewood used from harvested forest is increased from 20% to 30%.

Table 6
Energy Demand and Carbon Emissions in Brazil
Business as Usual Scenario - (2025)4

| | energy demand | | emissions |
|---|---|---|---|
| | Millions Toe | % | MT-C |
| Hydro-energy | 156.2 | 27.7 | - |
| Nuclear | 0.7 | 0.1 | - |
| Coal | 109.6 | 19.4 | 138.5 |
| Oil products | 227.5 | 40.4 | 260.2 |
| Natural gas | 16.8 | 3.0 | 11.2 |
| Firewood | 29.7 | 5.2 | 24.1 |
| Sugarcane | 22.4 | 3.9 | - |
| Total | 563.0 | 100.0 | 434.1 |

Source: Santos (1993)

Table 6 shows a substantial increase in energy consumption and emissions as compared to 1990 (almost 6 times higher). In the business as usual scenario, oil products and coal will be major contributors to Brazilian energy sector emissions. Coal emissions will increase very rapidly (8.3% yearly) as a result of coal substitution for charcoal in the steel industry, and the use of coal for electricity generation as well. The share of thermal electricity generation capacity is estimated to increase from 14%, today, to approximately 35%, in 2025. Coal fueled power plants are estimated to contribute to 60% of thermal electricity generation. Although these estimates are probably too pessimistic[8], they offer a reasonable overview of the likely trend if no policies are introduced to curb down $CO_2$ emissions.

## 3 - Patterns of Energy Demand in Brazil: Main Determinants

Brazilian economic development was characterized by a striking industrialization process between World War II and 1980. In this period, import-substitution was the strategy adopted to push economic growth. In order to induce domestic production of imported industrial goods, very substantial tariff and non-tariff barriers were introduced to protect domestic producers from foreign competition, and financial and fiscal incentives were provided to induce domestic investments in industry as well.

Macroeconomic policy focused attention on the foreign exchange constraint. Issues such as budget equilibrium, inflationary pressures, savings, relative prices distortions, were all undervalued by government policies. The main macroeconomic concern was the trade balance.

Presently, Brazil has a solid and diversified industrial structure, indicating that the main aim of the import substitution strategy was achieved. However, this strategy generated economic and social distortions:

First, the lack of adequate government activities financing created a huge fiscal deficit. Political difficulty to enforce higher taxes led governments to induce inflation as a mechanism to finance government policies. As a result, Brazilian industrialization was followed by a remarkable inflationary process[9];

Second, agriculture was severely penalized by import substitution policies. Financial resources were transferred from rural producers to industry through both direct taxation and price control of rural products. This policy induced uncoordinated migration of the rural population to large cities leading to extreme pressure on public services;

Third, the Brazilian industrialization process was accompanied by a large concentration of wealth. The upper social groups increased their income at greater speed than the large majority of the population. Today, Brazil figures among the worst income distribution situation in the world (World Bank, 1994).

## 3.1 - Industrialization and Energy Consumption

In the 1950s, the Brazilian government started an aggressive industrialization plan (Lessa, 1981). Huge investments in infra-structure (electricity, oil and steel) were made by state-owned companies while private capital, both domestic and foreign, invested in down-stream industries, specially the metal-mechanical complex. Many multinational companies installed production plants pushing industrial output to increase rapidly despite a period of political turmoil.

When the oil crisis started, the military government decided to move forward the industrialization process. It launched a very ambitious import substitution plan aiming to develop domestic production of capital goods, materials and energy (Castro & Souza, 1985). Huge investments, financed with petrodollars, were made by state-owned companies in energy, materials, transport, and telecommunication. To reduce energy imports, three programs were launched:

alcohol to substitute for gasoline (de Oliveira, 1991), nuclear to generate electricity (to avoid future imports of fuels), and domestic oil production (Araújo & Ghirardi, 1987)[10]. Private investors received large fiscal and financial incentives to increase domestic supply, and eventually increase exports, of iron, steel, pulp, paper, cement, petrochemicals, aluminum and fertilizers.

Although the plan intended to leapfrog the Brazilian economy to a modern industrial society, its outcome was the 1980's lost decade. Indeed, after a first blow of industrialization induced by easy access to petrodollars, the situation drastically changed soon after the Mexican default. Capital inflow to Latin America was reversed, forcing the Brazilian government to a complete review of its industrialization policy. Unable to introduce macroeconomic policies to cope with the new financial situation, successive Brazilian governments induced a chronically high inflationary process that imposed very substantial hurdles to new investments. Industry responded to this context, driving their strategy to exports and higher productivity[11].

The Brazilian industrialization process was accompanied by a substantial increase of energy intensity (table 7). Between 1965 and 1991, the Brazilian economy increased its energy consumption per unit of GDP from 0.29 to 0.51 Kg of oil equivalent. The electricity intensity increased more rapidly yet: from 0.28 to 0.77 Kwh/US$. The pace of growth of these intensities was fierce during the period of import substitution but diminished substantially soon after the oil crisis. At the end of the 1980's, the new context of oil availability at low price pushed up the energy intensity of the Brazilian economy once again, indicating that oil prices do matter as far as energy efficiency is concerned.

Table 7

Economic Growth and Energy Consumption - 1965-1991

| | 1965 | yearly average growth | 1973 | yearly average growth | 1979 | yearly average growth | 1985 | yearly average growth | 1991 |
|---|---|---|---|---|---|---|---|---|---|
| **A) Economic Activity** | | | | | | | | | |
| Agriculture | 15.86% | 4.38 | 12.52% | 2.50 | 9.81% | 2.88 | 9.79% | 2.93 | 10.71% |
| Industry | 31.96% | 9.43 | 36.43% | 5.58 | 34.43% | 2.89 | 34.41% | 0.85 | 33.31% |
| Tertiary | 52.18% | 7.12 | 50.66% | 8.48 | 55.76% | 2.91 | 55.79% | 1.46 | 55.98% |
| GDP (US$ billions) | 85.9 | 7.51 | 153.4 | 6.76 | 227.2 | 2.90 | 269.7 | 1.40 | 293.2 |
| **B) Energy Consumption** | | | | | | | | | |
| gasoline (Mm3) | 6.1 | 9.81 | 12.9 | 0.80 | 13.5 | -8.97 | 7.7 | 4.97 | 10.3 |
| Fuel oil (Mm3) | 5.3 | 12.19 | 13.3 | 5.05 | 17.9 | -10.46 | 9.2 | 0.75 | 9.6 |
| Diesel (Mm3) | 4.4 | 7.76 | 8.0 | 13.67 | 17.3 | 2.22 | 19.7 | 4.00 | 24.9 |
| Alcohol (Mm3) | 0.2 | 6.62 | 0.3 | 38.90 | 2.2 | 24.36 | 8.2 | 6.38 | 11.9 |
| Electricity (Twh) | 24.3 | 10.19 | 52.8 | 7.28 | 111.0 | 7.73 | 173.6 | 4.45 | 225.4 |
| Coal (Ton.) | 2.9 | 4.42 | 4.1 | 10.93 | 7.6 | 12.60 | 15.6 | -2.59 | 13.3 |
| Electricity/GDP (Kwh/US$) | 0.28 | 3.33 | 0.34 | 6.02 | 0.49 | 4.70 | 0.64 | 3.01 | 0.77 |
| Energy/GDP (Kgoe/US$) | 0.29 | 4.52 | 0.37 | 2.12 | 0.43 | 1.00 | 0.45 | 2.09 | 0.51 |

(Note: constant US$ 1989. Source: Araújo & ali, 1993)

These trends were the result of both increase of energy consumption in transportation and the growing share of energy intensive industries (e.g., aluminum, iron/steel, cement, pulp/paper) in industrial output (de Oliveira & ali, 1995). Indeed, the industrial share of total energy consumption jumped from 27.0% to 44.4%, between 1970 and 1993[12], despite a very substantial effort made by the Brazilian industry to improve its energy efficiency (table 8).

Table 8
Industrial Energy Consumption and Intensity

| | Energy Consumption - MToe | | | | intensity - PJ//US billions of 1990 | |
|---|---|---|---|---|---|---|
| | 1970 | 1980 | 1990 | 1993 | 1980 | 1990 |
| pulp/paper | 1.19 | 3.67 | 5.13 | 6.41 | 29.465 | 28.221 |
| chemicals | 1.67 | 2.07 | 2.48 | 2.51 | 7.653 | 6.134 |
| cement | 1.48 | 3.28 | 2.82 | 2.56 | 51.291 | 51.653 |
| iron/steel | 3.60 | 10.34 | 17.62 | 15.86 | 11.721 | 9.868 |
| non-ferrous metal | 1.06 | 3.97 | 8.52 | 9.49 | 30.630 | 27.744 |
| food | 5.98 | 9.28 | 10.32 | 11.80 | 86.684 | 80.032 |
| textile | 1.17 | 2.07 | 2.48 | 2.51 | 111.430 | 125.635 |
| others | 5.03 | 16.17 | 16.36 | 20.35 | 12.951 | 12.197 |
| Total | 21.18 | 50.85 | 65.72 | 71.50 | 22.179 | 22.036 |

Source: MME (1994)
Note: PJ = Peta Joule

At the end of the 1980's, it became clear for Brazilian policy-makers that import substitution policies were no longer able to induce economic development. Profound economic reforms started being introduced to adjust the Brazilian economy to the new international context. The long established protection for domestic producers started being progressively removed and the privatization of state-owned companies was initiated as well. A new economic stabilization plan[13] was launched with good results so far: GDP growth was 4.2%, in 1993, 5.0%, in 1994, and is expected to be around 5.0%, in 1995 while inflation remains at a relatively low level (roughly 1.5% a month).

It is important to remark that this growth, although strongly influenced by industry, is no longer driven by it. Nevertheless, a recent study of the Brazilian industrial sector (Coutinho & Ferraz, 1994) concluded that several agro-industries (coffee, soy-bean oil, orange juice) and material-industries (petrochemical, oil, aluminum, iron & steel, paper & pulp) have strong competitive advantages to sell into foreign markets. It is most likely that these industries, *that are energy-intensive*, will play a substantial role in the future economic growth of the country. Therefore, they should put pressure on energy consumption.

The Brazilian industry made a very substantial effort of technological up-date, in the last 10 years, in order to increase productivity[14]. This modernization is most often producing a substantial improvement of their energy efficiency as well. Hence, it seems likely that the energy intensity of the Brazilian industrial sector will remain relatively stable in the near future.

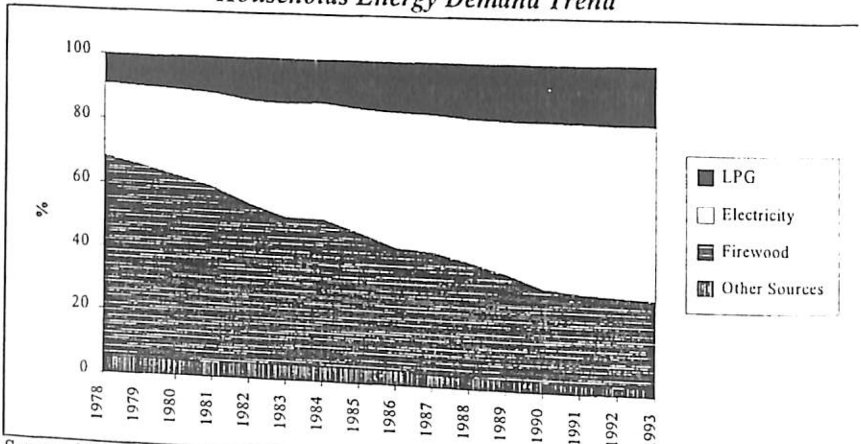
The pressure for augmenting the energy-intensity of the Brazilian economy should come from transportation and households. Indeed, there is a large share of the Brazilian population that has not had access to the benefits of industrialization as yet. Most of the energy intensive home-appliances are far from saturation and the number of cars per inhabitant is still very low[15]. As far as transportation is concerned, it is worth noticing that the Brazilian transportation system is very inefficient. Indeed, about 60 percent of freight is carried out by trucks and urban mass transportation is made mainly on buses as well. A shift from roads to railroads and waterways is necessary to reduce the energy intensity of transportation. However, this shift is very costly and unlikely to happen if no drastic changes are introduced in transportation policies.

### 3.1.2 - Population Growth and Urbanization

Between 1950 and 1994, the Brazilian population increased from 52 million to 155 million inhabitants pushing energy consumption to increase rapidly. It is true that the rate of population growth is falling but it remains relatively high as yet. This trend is a major driving force of energy consumption as yet.

In the same period, the share of urban population increased from 36.2% to 78.0%. The migration from rural to urban areas was accompanied by a very substantial change in the pattern of energy consumption. In urban areas, electricity and LPG are available while firewood is difficult to find. Unsurprisingly, the share of traditional energy sources used among householders has rapidly decreased (Figure 1). The spread of electrical appliances induced a rapid increase of electricity consumption while LPG was substituted for firewood[16]. It is important to remark that despite an increase of useful energy consumption for cooking the final energy consumption was reduced since this substitution of LPG for firewood produced a substantial improvement in energy efficiency[17].

*Figure 1*
*Households Energy Demand Trend*




*Source: MME (1994)*

Total energy consumption in the residential sector increased at a slow pace in the 1970's and 1980's (from 23.5 MToe in 1970 to 29.5 MToe in 1993) mainly as result of the substitution of firewood for LPG. Indeed, consumption of commercial energy sources increased enormously in the same period, from 4.7 MToe to 21.7 MToe (MME, 1994). However, the substitution of LPG for firewood is completed in urban areas and LPG is largely used in rural areas as well. Moreover, it is expected that the process of urbanization will slow down in the near future. Therefore, we can expect that households energy demand will be pushed by the spread of home appliances and cars among Brazilian families.

As pointed out earlier, Brazilian economic development was characterized by an uneven income distribution. A very large share of Brazilian families have no access to proper housing, health care and education as yet[18]. Government plans are to reduce the large disparity of income among families, spreading the benefits of economic development to these families. This process will most certainly increase home appliances ownership among Brazilian families. Although this ownership augmented rapidly in recent years (table 9), it still remains very low for most appliances. It is interesting to remark that despite the economic crisis, the share of families having a car increased from 15% to 26% in the 1980's, indicating that any improvement in income among lower income families is likely to increase car ownership very rapidly.

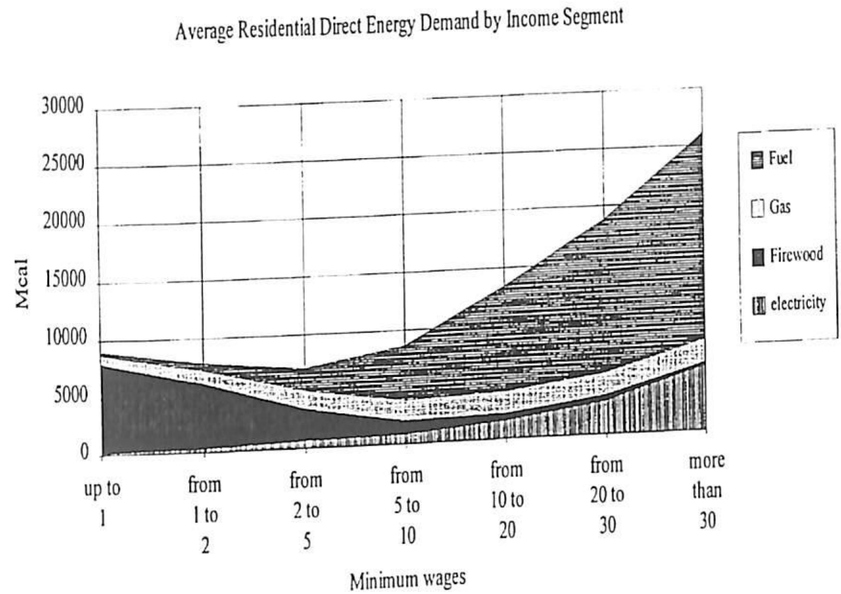
Table 9
Ownership of Appliances in Brazil (% of households)

| | 1974/75 | 1988 |
|---|---|---|
| Cars | 15 | 26 |
| Electric showers | n.a. | 64 |
| Air conditioners | n.a. | 6 |
| Electric irons | 66 | 89 |
| Microwave ovens | n.a. | 3 |
| Freezers | n.a. | 9 |
| Refrigerators | 36 | 71 |
| Washing machines | 7 | 22 |
| TV sets | 39 | 84 |

Source: Saboia (1983) and IBC (1992)

Figure 2 is an estimate of energy consumption by income level among Brazilian families. This estimate was made using appliances and car ownership's, and specific energy consumption for each appliance. Families with monthly income between US$ 65 and US$ 650, have no substantial difference in the *quantity* of energy consumed. However, there is a very substantial difference in the *quality* of the energy these families consume. The energy mix of lower income levels is dominated by traditional fuels (firewood) while the mix of higher income levels is commanded by modern fuels (mainly gasoline). Families with monthly income level higher than US$ 650 are very intensive energy users, specially gasoline. These figures suggest that income distribution policies will have a very large impact on the mix of future energy demand, specially fuels for family transportation.

*Figure 2*




*Note: the minimum wage in 1988 was, approximately, US$ 65,00*
*Source: Own elaboration*

## 3.2 - Energy Policy

Between World War II and 1980's, the main objective of the Brazilian energy policy was to develop the supply infrastructure in order to foster energy consumption. State-owned companies were created to develop the domestic market for fuels and electricity:

**Petrobrás** had the legal monopoly to explore, to produce, to refine and to transport oil (and natural gas); distribution is a competitive market where several companies, including Petrobrás, are looking for consumers.

Electricity is supplied by a mix of state-owned companies; generation and transportation are controlled mainly by federal companies while distribution is done by provincial companies[19]; **Eletrobrás** is the holding company that governs the Brazilian electricity supply industry (ESI);

Poor quality of domestic coal limited the development of both private and state-owned companies[20].

### 3.2.1 Supply Side

The monopoly of Petrobrás drastically reduced market, political, and geological risks, offering an excellent context for the rapid development of the oil market. Within 40 years, Petrobrás developed the Brazilian oil industry very successfully (Petrobrás, 1994). Domestic oil consumption increased to 1.3 million b/d in 1993, representing 2.5% of the world oil market. There are 13 refineries in the country that have capacity to process 1.5 million b/d. Oil production increased from 27,700 barrels/day in 1957 to 700,000 barrels/day presently. Large oil fields were found off-shore in the 1980's, increasing oil proved reserves to 3.8 billion barrels. Oil imports should be progressively reduced since domestic oil production is expected to reach 1.4 million b/d in 5 to 6 years.

The Brazilian ESI was initiated by private foreign investors. However, the lack of private investments led the industry to provide a very poor quality of service after WW II. This circumstance led both state and federal governments to develop the electricity supply infrastructure (Melo & ali, 1994), progressively eroding the role of private companies in the ESI. In 1962, a holding company (Eletrobrás) was created to coordinate and to centralize financing, planning and operation of the ESI. Under the leadership of state-owned companies, installed generating capacity increased from 1.9 GW in 1950 to 52.1 GW in 1993. Over 150 000 Km of transmission lines were built to interconnect many town grids; today, there are two large interconnected grids, only the Amazonia region remaining isolated. In 1993, 90% of Brazilian householders had electricity supply, the remaining non-connected families are living in rural areas, distant from the main urban areas.

The alcohol program was launched soon after the oil crisis started, taking advantage of the large Brazilian experience with sugar cane production (Copersúcar, 1989). Its initial aim was to add anhydrous alcohol to gasoline (up to 22%) but the critical situation faced by the Brazilian economy at the end of 1970's led the government to propose the production of alcohol cars to substitute for gasoline cars (Oliveira, 1991). Large subsidies were given to alcohol producers, car manufacturers and alcohol car owners in order to rapidly spread the use of hydrous alcohol instead of gasoline cars. In 1994, roughly 5 million alcohol cars were traveling on Brazilian roads, consuming 13.5 millions $m^3$ of alcohol (6.7 millions toe).

Since the collapse of the oil price, in 1986, the alcohol program is being criticized for the large subsidies that are needed to keep alcohol competitive with gasoline. Indeed, the hydrous alcohol program was launched assuming that oil price would remain at very high levels (over US$ 30/bbl). Progressively, the subsidies for alcohol producers, car manufacturers and alcohol car users are being removed, despite the strong support given to the alcohol program by environmentalists. Unsurprisingly, the share of alcohol cars sold reduced from 95% in 1985 to less than 3% nowadays. This trend suggests that, in a business as usual scenario, the alcohol car fleet will be progressively reduced and, in the near future alcohol, will be only used mixed with gasoline.

The construction of the first Brazilian nuclear power plant (Angra I) was initiated in 1968 (PWR/Westinghouse). In 1975, Brazil signed a nuclear cooperation program with

Germany that intended to develop the nuclear fuel cycle in Brazil and to built 8 nuclear power reactors (PWR/KWU) until the year 2000. Both objectives are far from being achieved: one of the two power plants initiated (Angra II) is still under construction while the other (Angra III) and all projects to develop the fuel cycle were abandoned. Angra I is operating but its performance is ridiculously poor so far. It seems reasonable to assume that no additional nuclear power plants will be constructed in the foreseeable future.

The use of natural gas is still very limited (Petrobrás, 1994), despite the relatively large Brazilian reserves (137.4 billion $m^3$) and large opportunities for imports (Bolivia and Argentina, mainly). Indeed, less than 3% of the Brazilian energy consumption is currently supplied with natural gas (4.9 billion $m^3$). The government policy is to rapidly increase the share of natural gas in the Brazilian energy balance but the network of pipelines that would bring natural gas from producing areas to consumers is underdeveloped still. Lacking financial resources, Petrobrás is unable to develop a pipeline network that would link the main industrial urban areas of Brazil to both domestic and international supply of natural gas.

In order to attract private investors to the gas industry and to accelerate the construction of pipelines, the legal monopoly power of Petrobrás on natural gas transportation was recently removed. The construction of a 16 million $m^3$ natural gas pipeline by private investors between Santa Cruz de la Sierra and São Paulo (going to Porto Alegre, in the extreme South of Brazil) was agreed with the Bolivian government[21]. This pipeline will link the major industrial areas of Brazil, creating the needed infrastructure to develop the natural gas market[22]. It is expected that natural gas will be substituted by fuel oil in industry, so that unincrease the future use of coal in electricity generation.

3.3.2. Demand Side Management

The first program aiming to improve the energy efficiency of the Brazilian economy (CONSERVE) was launched at the beginning of the 1980's. Its main guideline was to stimulate the diffusion of energy-efficient technology in industry, specially among small and medium size firms, but it has largely impacted large firms first. To induce conservation, firms were stimulated to create Internal Commissions for Energy Conservation (CICEs) that should monitor energy consumption; design and implement measures for energy conservation; develop and promote studies; and exchange technical information. Moreover, CICEs had to inform industry associations about the energy performance of their firm and industry associations then informed government of the aggregate results. These were to be used for energy efficiency monitoring and for policy-making as well.

Although no systematic assessment of CONSERVE was made, an evaluation of its results shows that it has been specially successful in substituting fuel oil but relatively poor as far as to energy efficiency improvement is concerned (Araújo & ali, 1993). The cement industry practically abandoned the use of fuel oil; the iron/steel and the pulp/paper industries both produced lower results, that nevertheless were impressive; other industries have substantially reduced their fuels consumption as well. The annual fuel oil consumption by industry reduced 7.7 million toe between 1981 and 1985 (MME, 1994), around 59.2 % of the fuel oil consumption in 1979.

More recently, energy conservation has been receiving much more attention from consumers, producers and policy-makers. The large difficulties faced by Brazilian energy suppliers to finance new projects and the trend for energy price escalation are both inducing players of the energy market to look closely to the large opportunities, in order to improve the energy efficiency. Currently, there are two governmental energy efficiency programs: PROCEL and CONPET.

PROCEL is run by Eletrobrás and it aims to promote the rational use of electricity. It was launched in 1985 and its action plan is structured in six group of activities:

***Information programs:*** technical manuals, seminaries and promotional campaigns to promote electricity conservation;

***Energy audits:*** 2400 have been carried out. Based on their findings, the following actions are considered priority: efficient lighting systems; replacement of oversized motors; good housekeeping of the electricity distribution network; better mechanical transmission; proper maintenance of air-conditioning systems;

***Technology development projects:*** so far they have been accounted for 40% of PROCEL budget. Resources have mainly gone to universities and research institutes, mostly for laboratory work, studies of equipment diffusion and use, and equipment development and tests;

***Appliance labeling:*** it is a powerful instrument for information diffusion, technological improvement and standards setting for the appliances industry. It usually involves a series of agreements between government officials, appliance producers and certifying laboratories over technical information and standards. Refrigerators, freezers, electric showers, and electric motors are already labeled. Air conditioners are the next appliance to be labeled;

***Public lighting***: half of the 1.2 million incandescent bulbs used have been replaced by mercury lamps and by efficient, high pressure sodium lamps;

***Incentives:*** special credit lines at real interest rates of 6-8.5% a year proved not to be attractive for consumers and were dropped in 1990. Informal post-mortems assessment points to insufficient publicity and narrowness of focus as causes of failure.

These actions saved 250 MW of generating capacity, an economy of US$ 375 million in foregone investments in generation, transmission and distribution[23] . The social cost of savings is estimated by PROCEL at 20 US$/Mwh saved, which compares very well with 60 US$/Mwh for system expansion, estimated by Eletrobrás.

More recently, the National Program for the Rational Use of Oil and Natural Gas Products (CONPET) was created (July 1991). Petrobrás is in charge of CONPET. Work is proceeding along four areas: promotion and information, inducement of efficiency-seeking behavior, improvement of equipment and system efficiency, and identification of regional solutions.

Besides these general areas of concern, five programs were set up: transportation, residential and commercial, industrial, agricultural, and electricity generation. The main goals of the transportation program are to reduce unit consumption and emissions of vehicles through efficiency improvements, and to switch the transportation mix from roads to waterways and pipelines. For the residential and commercial sector, actions are oriented to promote the use of natural gas to substitute for LPG. In industry, emphasis is laid on cooperation with the CICEs, and focus on large consumers to improve the efficiency of their fuels consumption. In agriculture, efforts are centered on reducing diesel consumption. Finally, efforts in electricity generation are directed to promote the use of combined cycle using natural gas and fuels other than diesel oil.

It is too early to appraise CONPET as yet. The program is in the process of receiving concrete shape in terms of resources and practical goals, and data regarding the few concrete actions are not available yet.

## 3.3 Institutional Arrangements and Pricing

The Ministry of Mines and Energy (MME) is responsible for policy making and monitoring performance of the Brazilian energy sector. The Ministry has an Energy Secretariat (SE) and two regulatory agencies: National Department for Fuels (DNC) and National Department for Water Resources and Electricity (DNAEE). However, the Ministry of Finance (MF) and the Ministry of Planning (MP) both play a very substantial role in the energy policy as well. Indeed, energy prices are decided by the MF while the MP decides on investment plans of federal state-owned energy companies.

As pointed out earlier, after WW II, the Brazilian energy sector has been dominated by state-owned companies. The hydrocarbons market was a legal monopoly operated by Petrobrás while the electricity market (although operated by several utilities) was being controlled by Eletrobrás, which acted as a holding company responsible for the coordination of system operation, long term planning and financing. The coal market was oriented to supply steel producers and its main supply (98%) usually comes from imports; there is a relatively small subsidized domestic production of steam coal (5 Million tons) used for electricity generation coming from private mining companies. The alcohol market is supplied by a few hundred of private alcohol distilleries but both production and subsidized prices are strictly controlled by government.

Ever since the oil crisis, energy prices have been settled with the main objective of minimizing the effect of price escalation in the inflation rate. For many years energy prices were escalated below increases in the retail index price (Araújo, 1991; Petrobrás, 1994). However, this was not the only objective. Energy prices have been largely used to support energy policy as well as regional, industrial and social policies. Indeed, very large cross subsidies were offered:

- to support the alcohol program and to develop domestic production of steam coal;

- to provide a single energy pricing rule to all consumers despite their location in the 8.5 million Km$^2$ of the Brazilian territory;

- to improve the competitiveness of large energy consumers (electricity); petrochemical producers (naphta); road (diesel oil) and air transport (jet fuel);

- to increase the actual income of low income level social groups (LPG and electricity).

This energy pricing policy, in a context of high inflation, produced very severe distortions in relative prices that are still present in the Brazilian market (table 10). In the case of oil industry, the impact of this policy was not very damaging, from the financial point of view, because Petrobrás discovered giant fields off-shore that reduced very substantially its costs. However, in the case of the electricity utilities the impact was extremely harmful, pushing utilities to a severe financial crisis (Oliveira, 1992).

TABLE 10
Average Energy Prices
(US$ 1993/ boe)

| Source | 1980 | 1985 | 1990 | 1993 |
|---|---|---|---|---|
| Oil | 53.7 | 39.7 | 25.6 | 16.3 |
| Diesel Oil | 88.5 | 95.5 | 43.4 | 57.8 |
| Fuel Oil | 34.7 | 43.6 | 22.3 | 25.6 |
| Gasoline | 230.0 | 150.3 | 97.6 | 94.1 |
| Alcohol | 180.1 | 151.9 | 113.9 | 115.3 |
| LPG | 63.5 | 59.9 | 30.1 | 46.6 |
| Natural Gas | 58.5 | 55.4 | 22.6 | 24.0 |
| Electricity for Industry | 102.8 | 95.5 | 87.1 | 85.2 |
| Electricity for Householders | 204.1 | 132.5 | 115.2 | 136.1 |
| Steam Coal | 11.3 | 12.5 | 8.3 | 9.3 |
| Charcoal | 36.8 | 26.0 | 15.8 | 15.1 |
| Firewood from Native Forest | - | 11.8 | 9.9 | 7.2 |
| Firewood from Planted forest | - | 16.2 | 14.0 | 11.6 |

Source: MME, 1994

As pointed out earlier, import substitution policies were abandoned in the 1990's. The previous government removed trade barriers, which have protected Brazilian industry from imports during the most of this century. Domestic producers are progressively being forced to adjust their business to global competition. Moreover, the new government[24] is introducing reforms in the Brazilian economy, aiming to increase the role of market forces in the economic fabric. An important aspect of these reforms is a complete restructuring of the institutional arrangements of energy markets both in terms of regulation and ownership (Oliveira & Pinto Jr., 1995).

The government declares that the main objectives of the energy sector reforms are to reduce the role of government through privatization and to introduce competition in the energy supply industries. It is expected that market forces will drive the industry to better allocate economic resources and to improve operational efficiency as well.

As far as hydrocarbons are concerned, the constitutional monopoly of Petrobrás was removed: **natural gas and oil production, transportation, trading and supply can be done by private investors**. The government policy is to keep Petrobrás as state-owned company and to open the hydrocarbons market for new players. In this case, Petrobrás will retain a chief role in the oil market and to a lesser extent in the natural gas market.

Regarding oil, Petrobrás owns all the oil production, refining and transportation facilities, and it controls the sedimentary basins that have a good likelihood of oil findings. Moreover, Petrobrás has already found very substantial oil resources that could increase its oil production to match domestic consumption. In this circumstance, it seems that the role of private investors in the oil industry should be relatively limited for many years as yet[25]. Financing is the possible constraint for Petrobrás since the stabilization program introduced strong limitations to public expenditures, including state-owned companies. However, oil products prices are being progressively adjusted to actual costs and it is expected that the large cross-subsidies provided by Petrobrás to alcohol producers will be removed as well. Therefore, the Petrobrás ability to finance its investments is likely to improve substantially in the near future.

In the case of natural gas, a consortium of private investors and Petrobrás will start the construction of the Bolivia-Brazil pipeline very soon. Moreover, since there are large reserves of associated gas and oil production is planned to increase rapidly, associated natural gas supply will increase substantially as well. Hence, the use of natural gas could spread quickly if the pipeline infrastructure is developed.

Indeed, the Brazilian infrastructure of pipelines is underdeveloped and there are no public funds to support new projects. Private investors that showed interest in the industry are asking for rate of returns for their investments that are substantially high (over 20%), obviously increasing transportation costs. Moreover, natural gas has to compete with fuel oil (in industry), diesel oil (in transportation) and LPG (among householders). Oil price is at relatively low level and there are cross-subsidies (at least for LPG and diesel oil) that both reduce the competitiveness of natural gas. Although there is a policy statement supporting the spread of natural gas, it is unclear to which extent this objective will be achieved.

Reforms in the ESI have already been introduced to prepare the sector for privatization. The nationwide equalized tariffs system[26] was discontinued, cross subsidies are being reduced and tariffs are increasing in order to recover full costs. Moreover, it has been decided that the transmission grid will be operated by a pool (called SINTREL) in order to offer free access for large consumers and to promote competition among generators. In order to introduce more competition in the system, a new law that compels any new franchising area was enacted to be submitted to a bidding system. Currently, a ministerial commission is studying a comprehensive restructuring of the electricity market that should introduce competition into the ESI and create room for the privatization of state-owned utilities as well.

The main force driving changes in the ESI is the very difficult financial situation of Brazilian utilities. It is widely perceived that the old institutional arrangement is no longer able to raise the financial resources that are needed to develop electricity supply in pace with increasing demand. Public funds are short and multilateral financial organizations are not prepared to offer new funds (World Bank, 1993). Privatization and a new organization of the electricity market are both perceived as mechanisms to attract private investors to the ESI and improve its efficiency as well[27]. It is expected that electricity utilities privatization will increase prices despite any increase on both operational and allocative efficiencies the reasons that private investors are looking for much higher rate of return for their investments.

These institutional changes are likely to have an expressive effect upon the structure of the Brazilian energy balance. Alcohol producers are under strong pressure since subsidies are being progressively removed while, in the ESI, thermal power is increasing its competitiveness as compared to hydropower[28]. These trends suggest that the role of renewable in the Brazilian energy balance is likely to be reduced in a future privatized energy sector.

## 4 - Options to Mitigate $CO_2$ Emissions

Soon after the 1972 United Nations Environmental Conference, the Brazilian government created a Special Secretariat for the Environment (SEMA) but very little was done to improve the environment until the 1980´s. Indeed, only in 1981 a law requiring any industrial project or civil work should prepare an assessment of its environmental impacts was created. In order to enforce this legislation, regulatory agencies were created at state level[29] and the National Council for the Environment (CONAMA) was created to coordinate their action.

At the end of the 1980´s, the constitutional debate[30] gave momentum to environmental protection. Indeed, strongly lobbied by environmentalists[31] the Brazilian Congress introduced an environemntal chapter in the new constitution that enlarged the role of environmental organizations in the policy making process. IBAMA[32] was created and a National Fund for Environmental protection was set up. In 1990, the Secretariat for the Environment (SEMAM), with the status of a Ministry, was created, settling the Brazilian institutional arrangements for the environment[33].

Crespo & Leitão (1993) used a statistically representative sample to assess the perception of the Brazilian population of environmental policy. They identified that Brazilians are happy with the quality of their environment. Moreover, Brazilians argue that their country is so rich in natural resources that there is no need to control its exploitation and most of they believe that science can solve any environmental problem. However, they feel that there is an ongoing process of environmental deterioration and that the Brazilian governments are not doing enough to stop it. Asked to list their environmental problems, they pointed out deforestation and pollution (water and air) as their main concern; climate change and global warming were listed as a problem by 28% and 17% of the sample respectively.

In order to reduce pollution, there are four (4) governmental programs underway:

- national Program for Water Quality (PROÁGUA) that intends to improve the situation of hydro-basins, particularly in industrial areas[34];

- national Program for the Ocean Environment that intends to control sea water pollution near industrial areas and oil terminals[35];

- national Program for Air Quality Control (PRONAR) that continuously monitor air quality, specially in industrial urban areas, and provides licensee for industry site;

- national Program for Motor Vehicles Pollution Control (PROCONVE) that forces Brazilian Motor Vehicle Industry to comply with US 1992 emissions standards by 1997[36].

As far as climate change is concerned, the major government interest is the impact of deforestation in the Amazonia region. An official statement indicated that so far the Brazilian government believe that there is no clear evidence to support climate change policies (CIMA, 1991). In order to reduce deforestation, the Brazilian government eliminated tax incentives that were largely used by cattle producers to clear forest land in the 1970's. Moreover, IBAMA is currently running a comprehensive program to prevent fire in Amazonia (PREVFOGO), with the support of the USA government. This program intends to identify sources of forest burning and to estimate their carbon emissions. Eventually, PREVFOGO will generate policies to avoid forest burning[37], specially the use of slash-and-burn technique in agriculture.

## 4.1 Opportunities for GHG Mitigation

The Brazilian energy sector is relatively clean as compared to both industrial and developing countries. This is because the Brazilian society is a very large user of renewable energy sources. Indeed, biomass is consumed both in industry and transportation while electricity is almost entirely generated by hydropower plants. Table 11 shows that $CO_2$ emissions from the Brazilian ESI are much lower than other Latin-American country, for instance.

Table 11
Tons of $CO_2$ per Gwh Generated

| | Argentina | Brazil | Mexico | Venezuela |
|---|---|---|---|---|
| 1975 | 640 | 63 | 414 | 665 |
| 1985 | 372 | 34 | 480 | 558 |
| 1992 | 441 | 37 | 472 | 370 |

Source: OLADE/SIEE

If the Brazilian energy sector might be considered clean, the same can not be said regarding to carbon emissions. Due to deforestation in tropical areas, these emissions are estimated to be between 150 to 220 MTon-C, around 2.2% to 3.1% of world total emissions (Reis, 1992). This means that $CO_2$ emissions from deforestation is 2 times higher than energy sector's emissions[38].

Santos (1993) assessed required energy policies in order to mitigate 25% (scenario 1) and 50% (scenario 2) of carbon emissions in 2025 as compared to the business as usual scenario described in section 1. To achieve these reductions, it will be necessary to introduce aggressive technological policies to increase both energy efficiency and the role of biomass (table 12) in the Brazilian energy balance. Moreover, the Brazilian hydropotential must be fully exploited and the spread of co-generation[39], specially in sugar mills, has to be encouraged[40].

Table 12
Biomass Share in the Energy Balance in 2025

| | share of alcohol in gasoline | share of pure alcohol cars | charcoal used for steel production | share of harvested forest |
|---|---|---|---|---|
| Scenario 1 | 22% | 60% | 30% | 50% |
| Scenario 2 | 22% | 60% | 45% | 60% |

Source : Santos (1993)

Table 13 shows the likely primary energy consumption of the Brazilian economy for the two alternative scenarios. In the year 2025, hydropower share in the energy balance would remain approximately the same in the two scenarios because at that point in time the Brazilian hydropotential will be fully exploited. The role of biomass is strongly reinforced in scenario 2 because alcohol will be largely used in transportation and charcoal in industry. Both oil and coal consumption would be drastically reduced in scenario 2 but it could be reduced further if natural gas use was fully developed. Indeed, the share of natural gas in both scenarios still remain too much low.

It is worth remarking that while in the business as usual scenario the total primary energy consumption is expected to reach 563.0 MToe. It should sum up 561.3 MToe or 652.8 MToe in scenarios 1 and 2 respectively, despite a very substantial effort to improve energy efficiency in these last two scenarios. This is because, in order to reduce $CO_2$ emissions, fossil fuels are substituted by biomass (firewood and sugar cane) that needs a much larger amount of primary energy to produce the same amount of energy service. Unsurprisingly, if we compare the business as usual scenario and scenario 2, we find out that fossil fuels consumption was reduced of roughly 170 MToe while the increase of biomass consumption was around 250 MToe.

Table 13
Energy Demand by Sources - 2025

| | Scenario 1 | | Scenario 2 | |
|---|---|---|---|---|
| | MToe | % | MToe | % |
| Hydro-power | 152.5 | 27.2 | 163.2 | 25.0 |
| Nuclear | 0.7 | 0.1 | 0.7 | 0.1 |
| Coal | 55.5 | 9.9 | 44.9 | 6.9 |
| Oil | 200.0 | 35.7 | 113.8 | 17.4 |
| Natural gas | 27.5 | 4.9 | 25.3 | 3.9 |
| Firewood | 51.5 | 9.2 | 144.9 | 22.2 |
| Sugarcane | 73.3 | 13.0 | 160.0 | 24.5 |
| Total | 561.3 | 100.0 | 652.8 | 100.0 |

Source : Santos (1993)

Table 14 suggests that very substantial reductions in $CO_2$ emissions can be achieved if aggressive environmental policies are put in place. However, even in the most optimistic scenario, the emissions will continuously increase in the next 30 years at roughly 5% a year. Comparing with the business as usual scenario (table 6), carbon emissions can be halved if environmental oriented energy policies are adopted immediately. It is clear from these figures that reductions in oil and coal consumption are the main factors behind this dramatic change in carbon emissions trends. It is important to remark that these scenarios have not exploited the potential for improve the reduce of $CO_2$ emissions through the rapid spread of natural gas use and changes in the modal mix of the transportation system. If such policies are enforced as well, it is possible to envisage a no increase in carbon emissions.

Table 14
$CO_2$ Emissions by Energy Source - 2025
(MTon - C)

| Source | Scenario 1 | Scenario 2 |
|---|---|---|
| Coal | 65.1 | 59.2 |
| Oil | 217.8 | 127.0 |
| Natural Gas | 19.0 | 4.1 |
| Firewood | 23.7 | 26.4 |
| Total | 325.6 | 216.8 |

Source : Santos (1993)

As we pointed out earlier, transportation is the most environmentally aggressive sector of the Brazilian economy. Carbon emissions produced by transport increased 111% from 1970 to 1990, representing 32% of total emissions. This trend led the federal environmental regulation office to establish a vehicle emissions standard that is quite limited[41]. Unfortunately, the impact of this policy is relatively restricted since the motor car fleet is likely to increase rapidly with growing family income. In order to substantially impact transportation related carbon emissions, it is fundamental a transition from road transportation to a modal mix where waterways and railroads will have a much larger role.

## 4.2. Economic Hurdles for a GHG Mitigation Program

The Brazilian government is working to fulfil its commitment concerning the Framework Convention on Climate Change (FCCC). The Ministry of Science and Technology is preparing a comprehensive assessment of GHG emissions in order to inform the international community about the Brazilian contribution to global climate change. This study should be available by the end of 1997 and it will be the foundation for an extensive GHG emissions policy that still does not exist.

Meanwhile, the Brazilian diplomacy has been assessing the current situation worldwide to inform energy policy-makers. So far, its assessment is not very encouraging.

Indeed, the Brazilian perspective is that *the present world social and economic reality has proven that it does not seem possible or even easy for Annex-1 Parties to actually take the necessary measures to bring their emissions in the year 2000 down to the level of 1990.* Moreover, *the limitation of the emissions at the present level or at 1990 level, even if such limitation continues beyond 2000, does not lead to the achievement of the objective of the Convention* (Brazilian Delegation at the United Nations, 1995).

This assessment is source of some concern. It indicates that there are economic forces that are playing against the objective of the Convention and even if the commitments are fulfilled the objective will not be achieved. Such, assessment obviously reduces the scope for domestic policies intending to mitigate GHG emissions, specially since Brazil is a relatively low GHG emission economy as compared to any industrial country. It is not surprising therefore that there is an widespread view among policy-makers that no action to reduce GHG emissions should be taken by Brazil unless industrial countries introduce effective measures to reduce their own emissions. In few words, **Brazil is most likely to be a follower than a leader in the effort to reduce GHG concentration rates.**

Nevertheless, the Brazilian energy sector is in a unique position to be environmentally clean. From the supply side, Brazil has a substantial potential for large production of renewable energy sources. There is an abundant hydropotential to be still exploited and biomass can be produced in large scale to supply energy needs as has already been proved by the alcohol program. Moreover, there are large areas of the country that can be used for planted forests and there is a huge potential for solar energy use. From the demand side, the Brazilian infrastructure of energy use is still under construction. Therefore, there are many opportunities for technological leap-frog to energy efficient end-use technologies (Goldemberg & ali, 1988) that would substantially reduce energy consumption.

Unfortunately, the future seems not to be as bright as it could and should be. Indeed, the share of biomass in the energy mix is decreasing, thermal power plants are likely to be the main source of new electricity supply and the energy conservation programs (PROCEL and CONPET) are losing ground. Moreover, the lack of financial resources is jeopardizing the development of natural gas supply, hindering the urgently needed modal change in the transportation system as well. There are at least three main hurdles that hinder the movement towards an environmentally friendly energy sector: oil price, financial resources and privatization.

As presented earlier, the Brazilian economy is a large user of biomass (sugar cane and firewood). Both alcohol and charcoal have had their competitiveness strongly enhanced by the escalation of oil price in the 1970's. Unfortunately, the current level of oil price is too much low as compared to actual costs of these renewable energy sources[42], forcing the Brazilian authorities to provide substantial subsidies for producers[43] despite a very substantial effort made by both alcohol (Copersucar, 1989) and charcoal producers to reduce their costs[44].

The current situation of Brazilian public finances is not healthy and the present government is making strong efforts to reduce public expenditures. Subsidies have been progressively removed and, consequently, biomass use has been reduced. This trend suggests that, unless oil prices be discharged, the future of biomass in the Brazilian energy balance will be reduced in the near future.

In the previous section, we indicated that the full exploitation of hydropower resources, the spread of natural gas use and the transformation of the modal transportation mix can substantially improve GHG emissions. It is important to note that these opportunities need very substantial investments in infrastructure that have a quite long lead time. These projects are not easy to finance, considering the new institutional framework of privatized public services. Indeed, although a large inflow of capital for public services after privatization is expected, it is important to have in mind that the high rate of return on investments (over 15%) required by private investors is a very serious hurdle for capital intensive investments with long lead time. For instance, in the case of electricity generation there is a widespread view that privatization will induce the energy sector away from hydropower.

Despite these difficulties, there are elements that are moving the Brazilian energy sector to reduce its GHG emissions. Indeed, the very large price distortions that were in place for many years are being progressively removed, inducing consumers to use energy more carefully. For instance, the Ministry of Mines and Energy recently created a program to promote alternative renewable energy sources in poor communities. Renewable energy sources such as solar, wind and small-hydropower can be specially interesting to supply energy demand in isolated rural areas and small communities in the north of the country. Currently, these isolated consumers are using diesel fueled power plants, spending around US$ 200 million per year on fuel. Renewable energy sources can substitute total or partially (mix system) the current diesel consumption in these areas.

The movement for a careful use of energy is being reinforced by energy conservation programs (PROCEL and CONPET) that are educating consumers and promoting energy efficient technologies as well. At present, the Congress is analyzing an Energy Conservation Policy Act that will induce utilities, equipment producers and consumers to invest in energy efficiency. Moreover, it is expected that the strong movement for the acquisition of the ISO-14000 quality standard will boost both energy and environmental efficiency of the Brazilian energy consumers (Otta, 1994).

The stabilization of the Brazilian economy and the drop of import substitution policies are likely to have a positive impact on GHG emissions as well. Indeed, these two movements are forcing Brazilian producers to adjust their processes to international standards. Moreover, environmental regulations are becoming progressively more stringent, reducing the amount of emissions that any producer can discharge into the environment.

## 5 - Conclusions

Although it is possible to anticipate a slow-down in the pace of Brazilian energy consumption, it shall be increasing substantially for many years, stimulated by strong economic and social forces. This trend will most likely push up Brazilian $CO_2$ emissions for many years still.

Our assessment of the trends in energy related emissions showed that the Brazilian energy sector became less harmful to the environment after the oil crisis. Energy policies were introduced to improve energy efficiency and to substitute oil. As result of these policies, the rate of growth of $CO_2$ emissions was slow despite a very substantial increase in energy consumption.

More recently, both economic and energy policies were drastically changed. Unfortunately, these changes are not likely to mitigate $CO_2$ emissions. Quite the reverse, there is evidence that fossil fuels are taking back the share of the energy balance that was won by renewables after the oil crisis. This is obviously a very disturbing development.

Nevertheless, Brazil is plenty of opportunities to reduce strongly the pace of these emissions. Indeed, there is a very large potential for renewable energy sources, specially hydropower and biomass, that can be exploited if sound policies are put in place. Moreover, for too many years Brazilian energy consumers have not been exposed to real energy prices. This context did not induce a rational energy consuming behavior. Since subsidies are being progressively removed there are many opportunities to improve energy efficiency that can be exploited in the near future.

We indicated that there are at least three hurdles that are holding back the development of an environmentally friendly energy sector in Brazil: oil prices, lack of financial resources and privatization.

There is little that Brazil can do to move oil price up or down but it seems reasonable to adopt a non-regret strategy as far as long term oil prices is concerned. It means that Brazilian energy policy-makers should assume an oil price at least 20% over current prices when designing their energy policies.

Movements have started recently to attract private investors to the energy and the transportation sectors. These movements are expected to increase the availability of fresh financial resources to support the very large investments needed to develop the Brazilian infrastructure. However, there are signs that private investors are looking for projects with short lead time and high rate of return. These conditions will move the power sector away from renewables and the transportation sector away from railways and waterways, therefore deteriorating the environmental performance of both. It is clear that the regulatory regimes, that have to be chartered before privatization, have to address carefully these issues. Probably the best market solutions are to provide mechanisms that can minimize private investors risks (to reduce the rate of return) and to attract investors that are interested in long term projects such as pension funds. However, it seems unavoidable that some power should be offered for the regulator in order to induce private investors to comply with stronger environmental regulations.

Despite these hurdles, we indicated that subsides for energy consumers and trade barriers have been both largely removed, inducing energy consumers to behave more efficiently. These movements are likely to reduce energy consumption, helping the Brazilian economy to achieve a sustainable energy path.

In any circumstance, it is fundamental to have in mind that the role of industrial countries in the Brazilian GHG policy is crucial. Indeed, the widespread perception among Brazilian policy makers that industrial countries should take the lead in the mitigation of $CO_2$ emissions is a strong constraining factor for the introduction of policies oriented to mitigate GHG emissions.

To remove this perception it seems indispensable that the Northern countries show a strong commitment to reduce their own emissions. If so is done, we believe that industrial countries can play a very positive role in the mitigation of Brazilian GHG emissions, offering technological and financial support that will be needed to provide an energy efficient and environmentally friendly energy sector.

## 6 - Notes

1 The IPCC concensus that the increase concentration of GHG in the atmosphere can potentially produce additionall warming of the earth surface induced both industrial and developing countries to search for a co-operative approach to deal whit GHG emissions.

2 This report does not deal with other environmental impacts of the energy sector. This is not because they are not important. Indeed, despite increasing regulations, the concentration of unhealthy gases, partircularly, in the industrial areas of Brazil have increased in the last 10 years (Gazeta Mercantil, October/3/1995). In order to reduce the impact of these emissions, the government of São Paulo State is introducing limitations for industry activity in the

main industrial areas and the use of motor cars in certain days of the week as well.

3 Petrobrás had found oil fields on-shore but was unable to supply more than 20% of domestic consumption. Nevertheless, Petrobrás refineries were supplying roughly 100% of domestic consumption of oil products.

4 Since electricity was generated from hydropower, there was an widespread perception that electricity could substitute for fuels.

5 Over 95% of the electricity generated in Brazil comes from hydroelectricity.

6 The 2015 plan expects thermal installed capacity to increase from 4.7 GW to 9.4 GW.

7 Petrobrás has been pressuring energy policy makers to reduce the share of anhydrous alcohol in gasoline arguing that it can no longer subsidise the alcohol program.

8 For instance, is quite likely that energy efficiency will improve and natural gas will have a large share of thermal power generation as well.

9 Between 1950 and 1980, Brazilian average annual inflation rate was 33%. In the 1980's, debt crisis induced a hyper-inflation process (the average annual inflation rate was 154% until 1985 and 624% until between 1985 and 1991). For a comprehensive review of the Brazilian anti-inflation policy (see Franco, 1995).

10 We will analyse this point with more detail in section 3.2.

11 Coutinho & Ferraz hold that these adjustments were defensive, resulting in downgrading the production process in several industries, i.e., decline of both product diversification and nationalisation (importation of raw material and spare parts).

12 For details about the Brazilian industry energy intensive sectors (see Araújo 1994).

13 The Real Plan (the name of Brazil's new currency).

14 In Brazil, approximately 670 industries already has their production process certified by ISO 9000 standards.

15 See next section.

16 Currently, 88% of Brazilian householders use LPG for cooking purposes.

17 The cooking efficiency improved 6% yearly between 1976 and 1991 (Araújo & alli, 1993).

18 It is estimated that around 30% of the Brazilian families are below the poverty line (Sabóia, 1991).

19 Politically, Brazil is a federation of states that elect their own government.

20 As pointed out earlier, coal is mainly used for steel production and it is largely imported.

21 Initially, the pipeline will transport 8 million $m^3$/day, but it can transport up to 16 million $m^3$/day.

22 This pipeline will have a strategic role in the Brazilian market since it will offer access to consumers for both imports from Argentina and domestic production as well.

23 At an estimated system expansion capital cost of 1 500 US$/ MW, and assuming a capacity factor of 55%.

24 General elections were held October 1994 and the new government took office January 1995.

25 The most likely scenario is that private companies will search for joint projects with Petrobrás.

26 In order to subsidise poorer regions of the country, there was the nationally equal tariff system until 1993 that forced low cost utilities to subsidise high costs utilities.

27 The Brazilian ESI is strongly criticised for very serious misallocation of economic resources (Medeiros, 1993).

28 Higher rate of return increases the competitiveness of less capital intensive technologies.

29 Brazil is a federation of States, in many ways similar to the USA.

30 As result of the end of the military regime in 1985, a new constitution was enacted by the Brazilian Congress in 1988.

31 For an overview of the Brazilian environmentalism see Crespo & Leitão (1993). They interviewed 72 environmentalists (activists, scientists, industrialists, government specialists, politicians) to produce a record of their ideas and action.

32 Brazilian Environmental Protection and Renewables Natural Resources Agency.

33 For a comprehensive assessment of the Brazilian environmental policy in the 1980's, see CIMA, 1991.

34 In the state of São Paulo, it was recently introduced a taxation for the use of river water by industry and there are heavy fines for the discharge of polluted material in rivers.

35 The main task of this program is to develop a strategy do deal with oil spillovers in the Brazilian coast.

36 The Brazilian motor fuels are relatively rich in sulphur but Petrobrás is progressively introducing desulphurisation units in its refineries to comply with the legislation.

37 It is estimated that around 51% of the tropical plant species exist only in Amazonia. Hence, any reduction in forest burning will have a major impact on the preservation of species as well.

38 It is important to note that estimates of deforestation's emissions are quite imprecise still. More research is needed to estimate carbon absorption by tropical forests.

39 For the time being, co-generation is marginally used, despite its economic advantage (Oliveira, 1995).

40 It is estimated that 10% of electricity will come from co-generators.

41 Indeed, they are only 2 or 3 years behind the Californian standards.

42 In the case of charcoal, when produced from native forest its competitiveness is proved but this is obviously not an environmentally friend solution.

43 Between December 1984 and October 1994 subsidies provided by Petrobrás to alcohol producers amounted to US$ 3.5 billion (Petrobrás, 1994). Currently, alcohol producers in the Southeast region are receiving US$ 58.00/boe while those in the Northeast are receiving US$ 88. 00/boe (Jornal do Brasil, November, 22nd 1995), prices that are both substantially over gasoline costs.

44 In the case of the steel industry, an extensive program to promote production of charcoal from planted forests in order to compete with native forest was developed. However, charcoal is largely coming from native forests still. IBAMA reacted to this situation creating strong obstacles to the use of charcoal.

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