LPG in Brazil: lessons and challenges

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Liquefied petroleum gas (LPG) is a fossil fuel and at the same time an important means to achieve sustainable development. As in many developing countries, this gas is in Brazil the most common first substitute for fuelwood in homes, combating deforestation and causing less hazardous emissions to the atmosphere. It can reach isolated areas without significant infrastructure investments, can be stored safely and can provide the basic services for the most needy, such as heating, cooking and lighting. Imported LPG had a very significant role in Brazil in the 20th century, when continent-scale distribution logistics were established, supplying the fuel to households at subsidized prices. In 2001, the subsidies were removed, correcting price distortions but creating even worse social and environmental problems. Moreover, the Brazilian LPG infrastructure is under the threat of obsolescence. The aim of this paper is to present the case of LPG in Brazil and to make recommendations in order to preserve the benefits obtained from the utilization of this fuel: cleaner environments through an affordable energy source.

1. Introduction

Liquefied petroleum gas (LPG) is a petroleum derivative that has a very important role in the Brazilian residential energy mix. Accessible by 98 % of all Brazilian households and 93 % of rural households [IBGE, 2002], it has historically been the first substitute for fuelwood, obtained from deforestation by poorer rural and even urban communities. LPG is a cleaner cooking fuel. Fuelwood burned in primitive stoves causes significant health problems for the most exposed populations: women, children, babies and the elderly [Goldemberg and Coelho, 2003]. Distributed in 13-kg pressurized bottles throughout the country, LPG reaches most of the population not served by the natural gas infrastructure. Besides, LPG saves electricity utilized for heating. The gas has been subsidized for a half-century by the government and encounters, together with diesel oil used in road transport, a bottleneck in the Brazilian refinery infrastructure[1]. As a result, imports soared in the 1990s, significantly affecting the external trade balance[2]. When LPG prices rise, poorer residential consumers cannot afford to pay. They replace it with fuelwood, causing more deforestation. This also occurs in urban areas and is not a recent phenomenon. In urban areas, many types of waste materials, such as construction debris, are used in addition to fuelwood [Jannuzzi, 1988].

LPG was subsidized until 2001, after which prices practically doubled, causing a shift to the use of alternative fuels. The provision of LPG for low-income users is a cause of major concern, since the gas is in many cases the most important energy carrier for basic uses such as cooking. Its importance derives mostly from: (1) the availability, easy maintenance and relatively low cost of LPG-fuelled cookstoves; (2) the well-established LPG delivery infrastructure throughout the country and; (3) the lack of infrastructure to deliver gas by pipes to households (in Brazil there is no district heating).

2. The history of LPG utilization in Brazil

Domestic use of LPG in Brazil started in 1937, when the Graf Zeppelin trips to South America were cancelled and the cylinders of propane rendered surplus as a result were distributed to 166 households. Before this, the main fuels for stoves and heaters were fuelwood, charcoal and kerosene. The cities of Rio de Janeiro and São Paulo had some infrastructure for gas from coal, basically for public lighting. Although petroleum has been produced in the country since 1939, LPG was imported from the US, Europe and, during World War II, from Argentina. The expanded consumption made necessary large quantities of imports of vessels and gas, as well as investments in logistics. In the 1950s several new distributors joined the market and the 13-kg metal bottle became the national standard. The national oil company Petrobras was established in 1953 and started producing LPG in 1955.

Once the infrastructure for production and distribution was established, consumption levels increased and diversified to uses other than stoves: water-heaters, schools, hospitals, hotels and leisure clubs. In the industrial sector it was utilized in plastics, allowing the indigenous production of toys, then in the textiles, glass and home appliance sectors.

Present in more than 42 million households throughout the country (98 % of the total), LPG is utilized by more than 150 million people and provides more than 350,000 direct jobs in 15,000 companies – including refineries, distributors, retailers and transporters [Cotta, 2003]. Final prices of LPG to consumer were, for three decades, uniform throughout the country, cross-subsidised by other petroleum products.

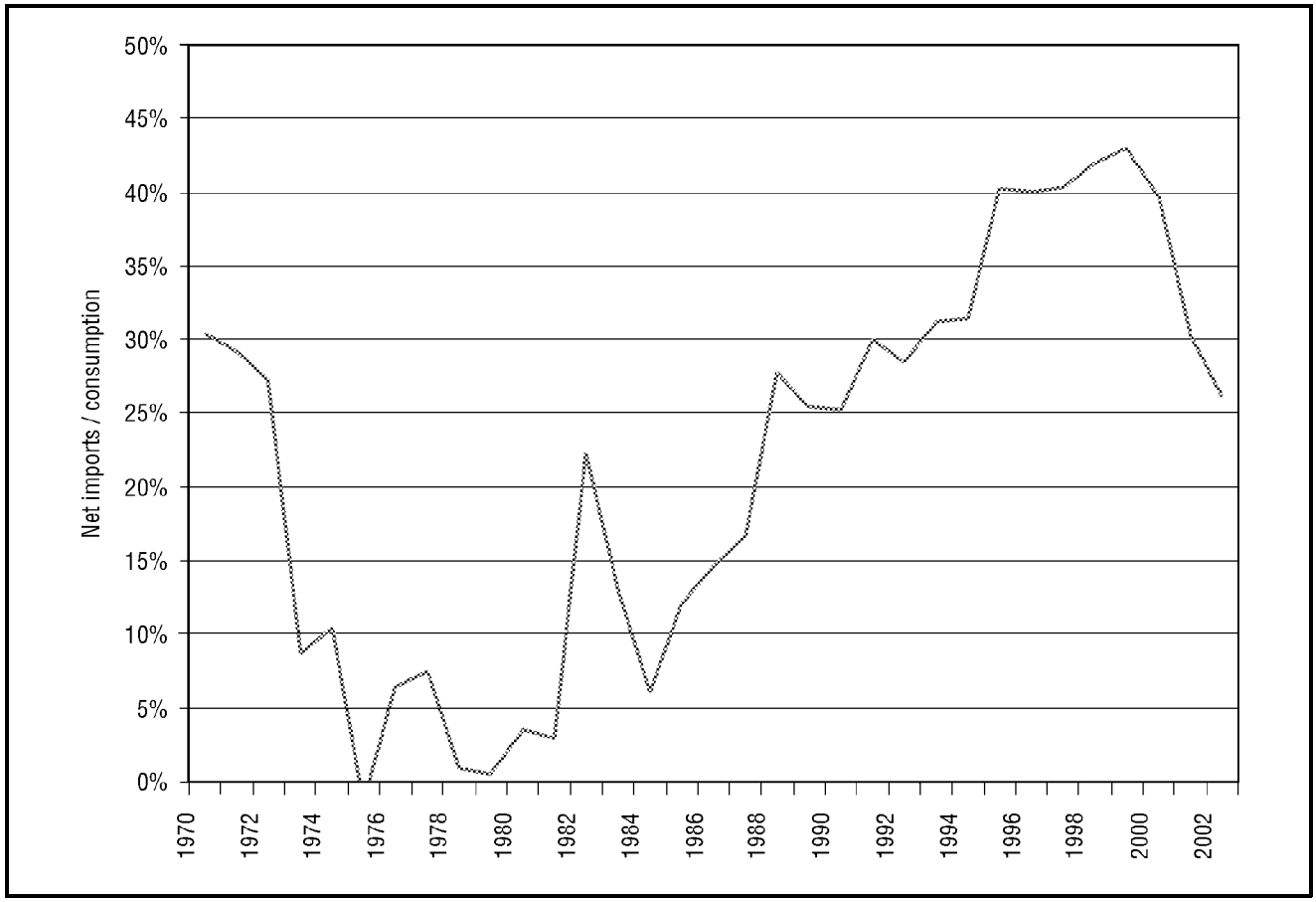

Figure 1. Brazil's dependence on external sources of LPG [ANP, 2003]

However, after price deregulation, such energy costs to households increased almost twofold, contracting the market and leading users to alternative and, in many cases, less sustainable fuels[3].

3. LPG supply

Around one-third of the LPG consumed in Brazil is imported and the rest is produced in domestic refineries or natural gas-processing units (Figure 1).

LPG constitutes 7.5 % of all petroleum products produced in the country and, together with diesel oil (35.3 % of the total), represents the largest element in the supply chain of the 94.4 million (M) m^3 of products supplied by refineries [ANP, 2003].

LPG production in Brazil peaked in 2002, at 8.9 Mm^3. Even so, it could not match the consumption of 12.1 Mm^3. The difference comes from imports, a dependence that has systematically declined with diminishing consumption after the peak of 12.5 Mm^3 reached in 1999.

4. LPG demand

Until the end of subsidies to LPG through the 2002 policy for market liberalization, it was a relatively affordable fuel.

In urban areas, its competition with natural gas is recent, after the investments in natural gas distribution made after the construction of a pipeline bringing Bolivian gas to the developed regions of Brazil. The competition was expected to intensify after September 2003, when discoveries of 419 billion (G) m^3 of natural gas (2.6 billion boe, barrels of oil equivalent) and 550 million tonnes (4 billion barrels) of oil in the country's offshore basins were announced.

After the 1999 consumption peak, the LPG industry has faced a systematic contraction in its activity. The business, which had witnessed annual growth of 3 %, had a projected volume in 2003 equivalent to that of 1996. The 2002 market deregulation greatly affected the sales to the residential and commercial sectors.

On the other hand, industrial use of LPG has increased in several sectors, from 4 % of total demand (or 0.29 Mm^3) in 1986 to 10 % (or 1.268 Mm^3) in 2001, especially in the ceramics (540,000 m^3), iron and steel (170,000 m^3), non-ferrous metals (114,000 m^3) and food and beverage (97,000 m^3) sectors [ANP, 2003]. Nevertheless, the profile of the end-user of LPG is far from changed: residential and commercial uses are still responsible for more than 80 % of total LPG consumption in the country (Figure 2).

The LPG balance in Brazil, with official trends made by the National Petroleum Agency [ANP, 2003], is presented in Appendix A.

5. Penetration in rural and urban areas

According to the Brazilian National Energy Balance, the residential fuel consumption is represented in Figure 3, where the substitution effect between fuelwood and LPG for cooking seems clear, although it should be noted that the fuelwood data in the National Energy Balance may not be accurate. The fuelwood use was calculated through

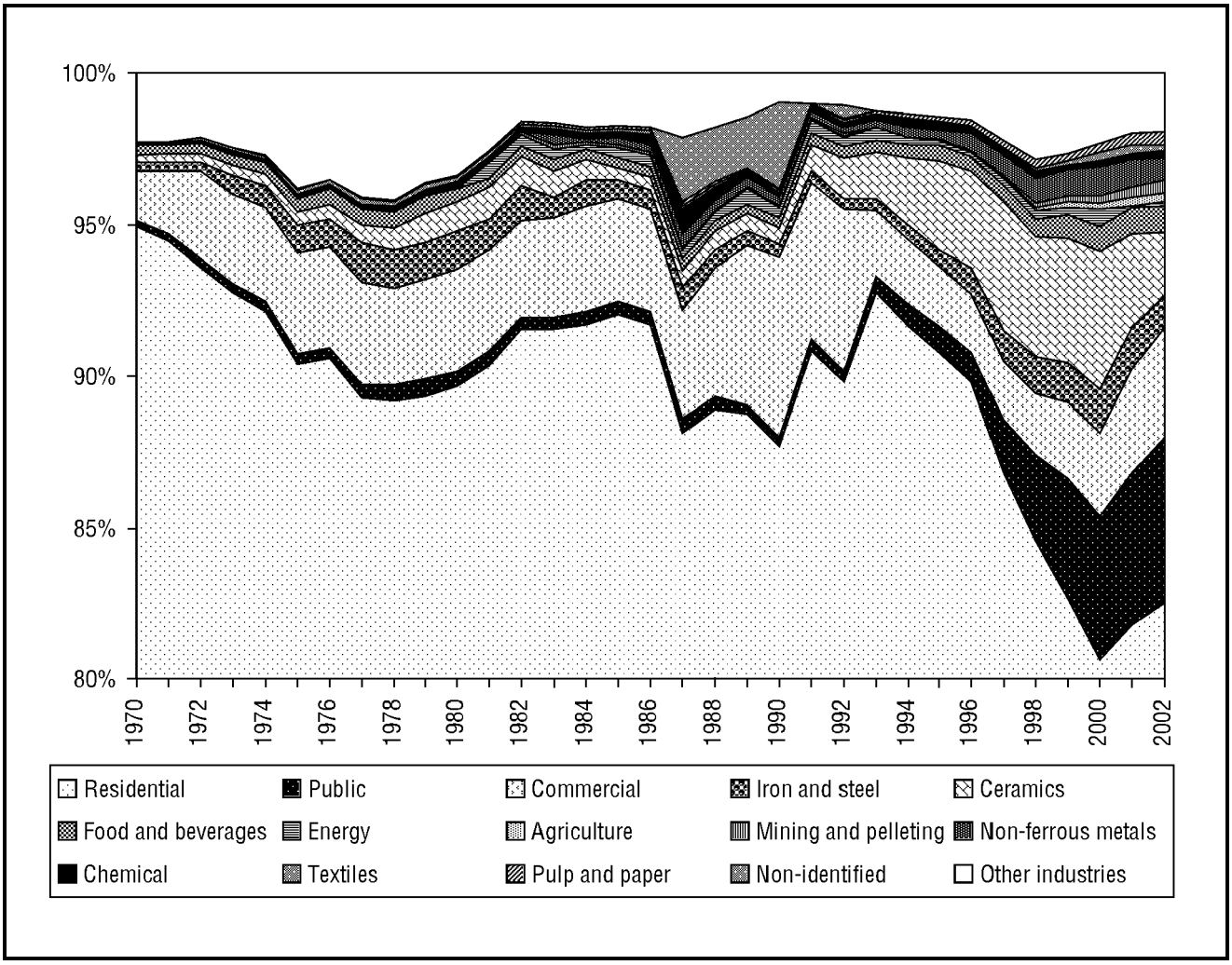

Figure 2. Shares of LPG consumption in Brazil, with the y-axis detailed above 80 % for non-residential uses [MME, 2003]

correlations with LPG, taking into consideration the number and type of stoves in each home provided by the National Census. The numbers for fuelwood are based on minimum household (3.8 inhabitants on average) requirements of 2.96 GJ/year in 2002 [Patusco, 2004][4].

Residential consumption of fuelwood and LPG are related through economic factors, as well as through strongly regional variables. For example, in the hot and less developed North-Northeast LPG is used basically for cooking, while in the Southern part of the country it is also used for heating water and industries. In poorer areas, where purchasing power is lower, families switch from the kitchen LPG cookstove to the primitive fuelwood stove located in their backyards. Motivated by a better knowledge of uncontrolled deforestation, Kamimura [2002] correlated fuelwood consumption with LPG and electricity consumption in different Brazilian regions, aiming at determining how end-use patterns vary according to time and location. In the country's most developed state, São Paulo, where there is a huge number of LPG final retailers, the per capita residential fuelwood consumption was the lowest (373 MJ per capita[5], compared to the Brazilian average of 1758 MJ/capita) in 2000. For the poorer Northern and North-eastern populations, fuelwood is the first option to substitute LPG in cooking.

As already mentioned, poorer families are especially sensitive to energy price increases and immediately adopt economy measures. One is to cook lunch and dinner just once a day and to avoid the use of the oven. The other is to utilize fuelwood in a backyard second stove, present in about 20 % of all Brazilian households, according to IBGE, the National Statistics Bureau.

The major part of this fuelwood is collected, increasing the rate of deforestation. The residential use of fuelwood is not one of the main causes of deforestation in the country (basically commercial wood-logging and land-clearing practices for cattle-raising and agriculture[6]), but this impact is severe in so-called "hot spots", outskirts of metropolitan areas where there still remain native forested areas.

That is the case on the outskirts of many urban areas, including the São Paulo metropolitan region with its 16 million population. This is also the case in semi-arid North-eastern Brazil, with considerable constraints on reforestation. The original *cerrado* forest is adapted to the harsh conditions and cannot be easily replaced by local reforestation projects. There, fuelwood represents 70 % of energy sources for cooking and 30 % of total energy consumption. A field survey conducted by Francelino et al. [2003] found an average of 0.33 m^3 of fuelwood use per family per month [MMA, 2003b]. In four states[7]

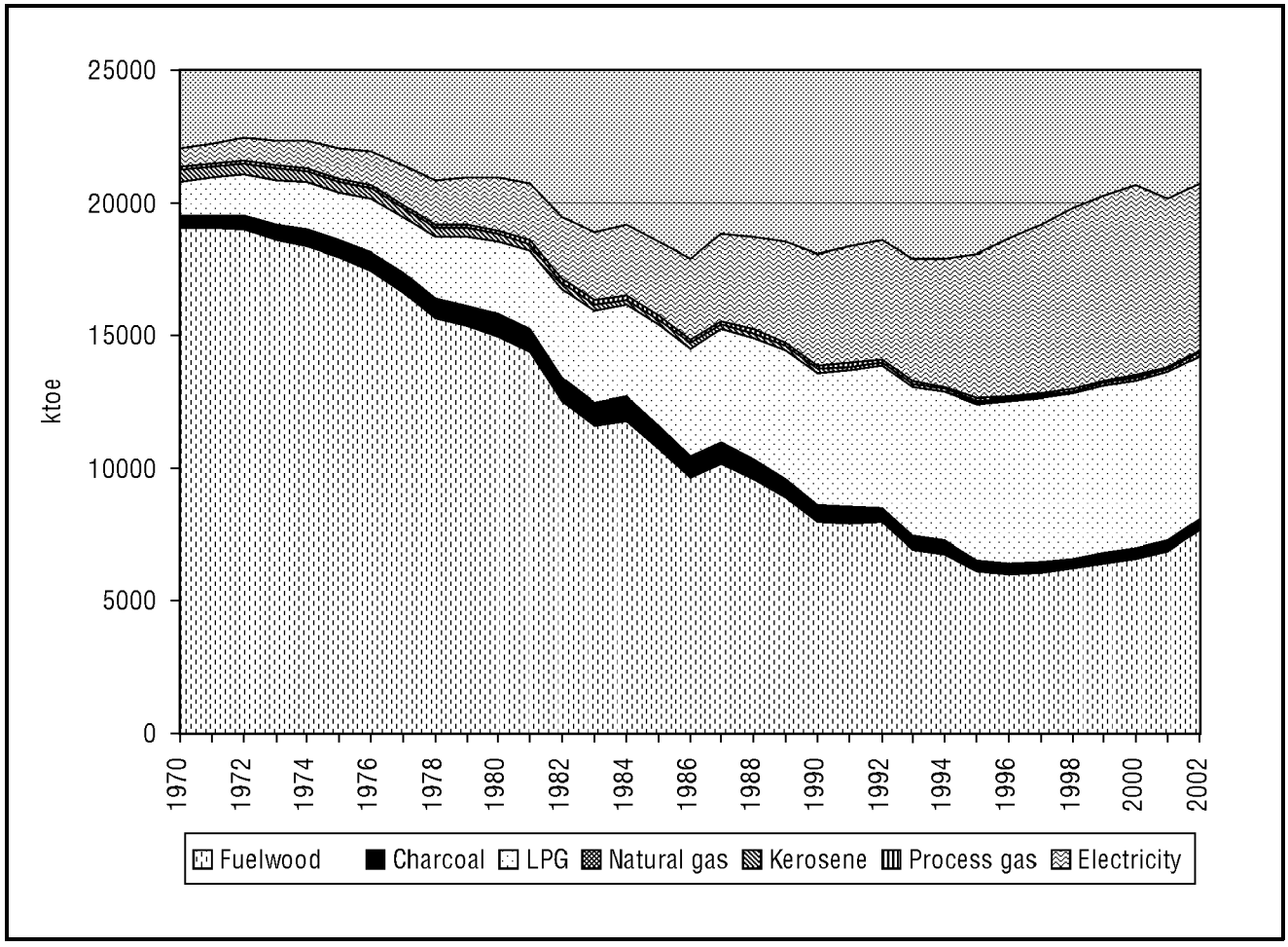

Figure 3. Residential fuel consumption in Brazil 1970-2002 [MME, 2003]. The units on the y-axis are kilotonnes of oil equivalent (ktoe). 1 ktoe = 44.8 PJ.

alone there are 77,000 fuelwood collectors who sell a m^3 for 6 Brazilian reals (R$) or around US$ 2. This is one of the only economic options available during the dry season.

In this region there are other types of "hot spots": many industries consume fuelwood for processing food and for producing ceramics. Fuelwood represents 21 % of the industrial primary energy requirements, of which more than 90 % comes from the arid region, incapable of recovering at such a rate of deforestation without governmental protection and energy alternatives [Neri et al,, 2000]. In the period 1982-1992 alone, the regional forest cover declined from 55.3 % to 44.6 %, a rate higher than that of the Amazon forest (0.3 %/yr). Protected areas account for 0.41 % of the North-eastern regional area, while the national average is 4 % [MMA, 2003a].

Another case-study is the South-eastern state of Minas Gerais, where the metallurgy industry was set up in 1937. Until the 1960s, the forests in the eastern part of the state were devastated by charcoal production in artisanal kilns. In the next twenty years, a governmental policy for reforestation (mostly with eucalyptus monocultures) increased the area from 62,000 to 2 million ha, creating the so-called "green deserts" and pushing other cultures to the North. In the 1970s, another policy provided incentives to new iron and steel industries in north-northeastern Minas Gerais, dislocating also the primitive charcoal industry to that region, destroying the *cerrado* vegetation [Guerra, 2002]. In the 1990s, modernization of the industry progressively replaced the *cerrado* fuelwood, but natural areas are still being invaded by monocultures. The region is at the limit of the semi-arid North-east, facing the same problems of residential and artisanal industry uses of fuelwood.

6. Policies for LPG in Brazil

From 1950 through 2001 the Brazilian federal government regulated LPG final prices to consumers. During that period, subsidies equalized the administered prices throughout the whole country. Companies had to receive and fill bottles from any distributor and comply with a series of standards and procedures. The excessive regulation and the use of LPG prices to curb inflation discouraged the entry of new distributors and hampered investments. In 1983 a quota allocation system was implemented, aimed at a fairer distribution of the available LPG among regions. It was replaced in 1989 by a distribution model, based on "primary supply bases" which concentrated the orders for gas made from decentralized bases [SINDIGÁS, 1990]. For households, the so-called "automatic delivery" system brings bottles to all municipalities, at intervals varying from one day to one month, plus an emergency delivery system. This consolidated a large distribution infrastructure.

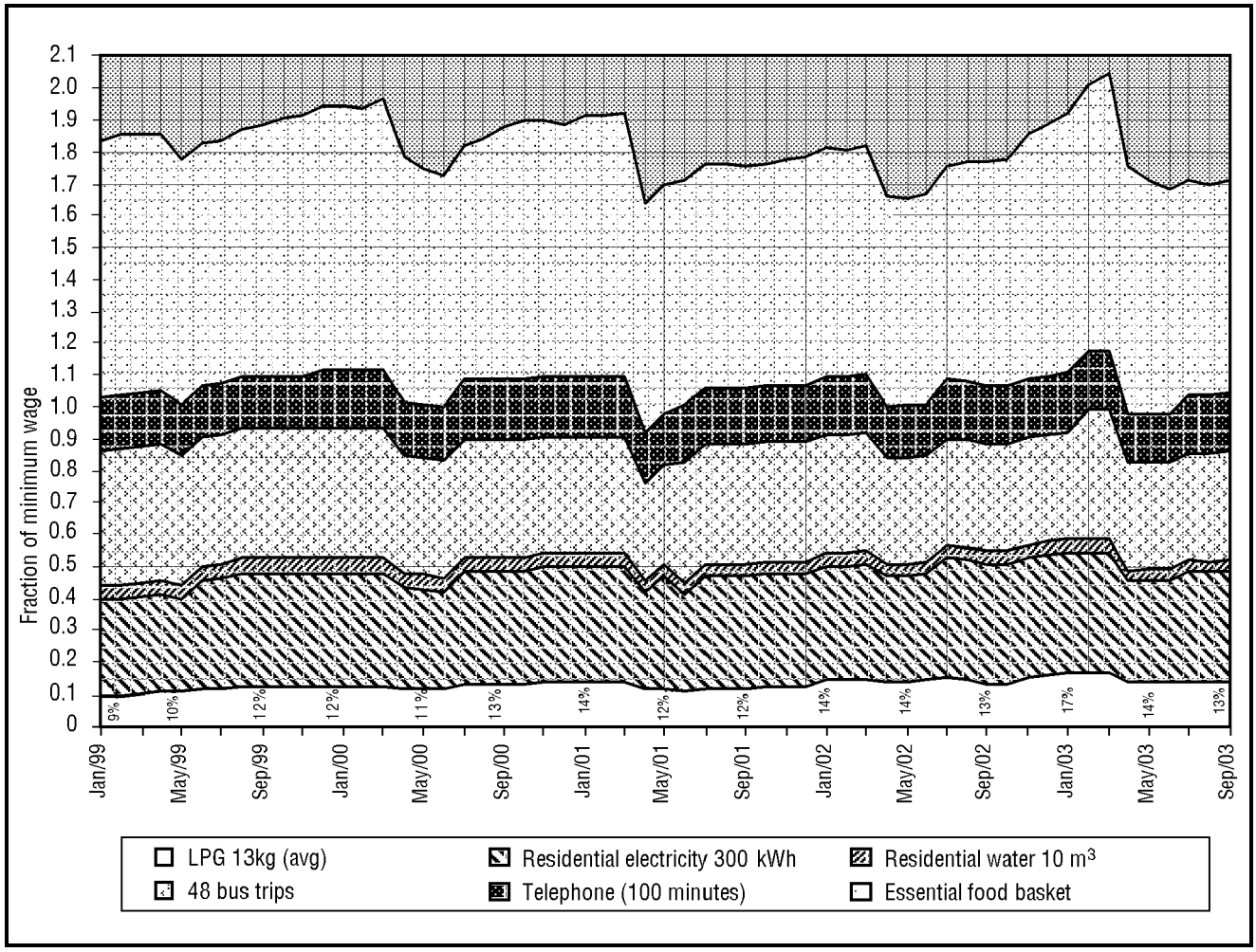

Figure 4. Basic living costs of gas, food, electricity, water, transportation and communication for a family in São Paulo, related to the value of a monthly minimum wage (equal to 1.0). The burden of a LPG bottle (i.e., the share of such total costs) is represented as a percentage in the vertical labels.

But problems occurred: the subsidized LPG started being put to other uses, such as heating swimming pools and saunas. Although the practice was prohibited, there were many vehicles utilizing it in clandestine and potentially dangerous adaptations.

By 2000, around US$ 100 million[8] was being spent annually to subsidize LPG in Brazil. Starting in January 2002 subsidies were removed. By the end of 2002 Petrobras, the state oil company, which imports the LPG utilized in Brazil, transferred to the consumer the international prices of the product. The free market raised the prices of a 13-kg bottle from R$ 21.9 (approximately US$ 7, or 11 % of the monthly minimum wage) to R$ 26.3 (a 20 % increase, Figure 4).

A few months later, Law 10453 created a program named Auxílio-Gas (literally "gas assistance"), which would transfer to low-income families subsidies for residential LPG obtained from a tax (constitutionally named "contribution of intervention in the economy"). Since then, approximately 9 million families earning up to R$ 100 (or 50 % of the minimum wage) have received R$ 15 every two months. However, this value was kept frozen, in spite of the increases in the LPG prices [Prado, 2003].

Residential fuelwood is usually gathered free of cost, but commercial and industrial fuelwood are mostly charged. The huge price differences between this last type of fuelwood (therefore more expensive than the "free" residential fuelwood) and LPG (for all uses) can be seen in Figure 5, which presents the pricing behaviour for different energy sources in Brazil.

It is important to note that fuelwood prices refer to the industrial sector, which uses the energy more efficiently than do homes. In the figure, electricity prices are higher but, compared to other energy sources, LPG prices soared by as much as 190 %, as seen in Figure 6.

Jannuzzi and Sanga [2004] attribute the subsidies that were used in Brazil in the past decades as a main reason explaining the high penetration of this fuel in the household sector. Subsidy is defined as any measure intended to keep the energy producers' costs below the market levels or to keep the end-users' retail prices below the market levels. There is no consolidated information on the exact amount of subsidy that was used to promote the massive distribution of LPG in the country, but the authors estimate the average proportion of subsidy to be 30 % of the ex-factory price and 18 % of the retail price in the period 1973-2001, reaching cumulatively US$ 8.235 billion. This value was corrected for inflation (constant 2001 US$) using the national price index (IGP-DI), coming down to

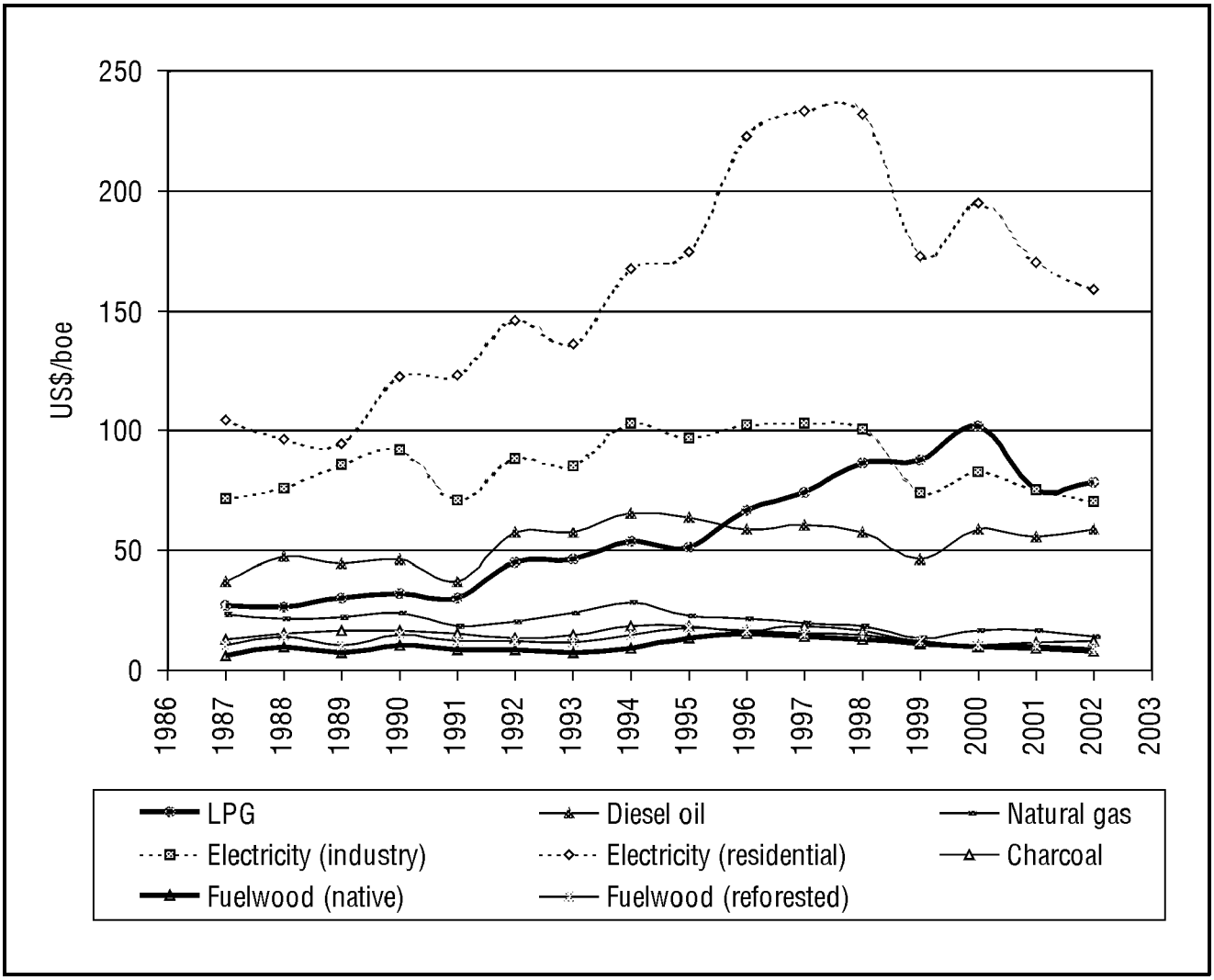

Figure 5. Retail prices of energy sources, in constant 2002 US dollars [MME, 2003]. Prices are shown in US$/boe. In energy terms, 1 barrel of oil equivalent = 136.4 kg of oil equivalent = 6.11 GJ.

US$ 2.929 billion. The average, inflation-corrected, per-capita subsidy amounted US$ 0.73, for an annual consumption of 40.32 kg/person, or approximately 2 GJ/capita.

7. Technical-institutional hurdles and effective policy measures

Today, the energy supply in Brazil, as in any cost-effective business, favours end-users who can pay for the fuel. That was the case for the privatized electricity production and natural gas distribution in the early 1990s. Today it is also happening with LPG after the removal of subsidies and pricing liberalization.

The Brazilian oil market started to open up to competition in 1995, when the Petrobras monopoly was flexibilized by an amendment to the Constitution. The 1997 "Oil Law"[9] regulated this new regime, creating institutions for policy-making and inspecting[10]. The Law limited state intervention in the market, orienting the upstream and downstream oil and gas prices. Five years after this change, there is broad competition in distribution and retailing of oil products. Such competition is limited in the exploration and production sectors and virtually non-existent in the transport and refinery sectors [Bandeira, 2003].

Petrobrás [2003], the national oil company, says that the refiner is only responsible for 42 % of final prices, with 21 % going to taxes and 37 % to distribution companies. According to oil company information 5 out of 18 distributors, the majority associated with multinational companies, control 83 % of the LPG market, and they are free to obtain the gas abroad, as international and domestic prices are the same [Manso, 2002]. In its turn, Sindigas, the distributors' syndicate, is seeking reductions in the taxes charged on LPG (corresponding to 25 % of the retail price), the creation of a price stabilisation fund (reducing price volatility), and an increase in the amount paid by Auxílio-Gás to each family [Jornal do Brasil, 2003]. Trapped in this deadlocked discussion on who is to blame for high prices, the final consumer pays the price.

Jannuzzi and Sanga [2004] estimated for this current gas voucher system an annual subsidy of US$ 16 per capita for the low-income families in the programme – a value by far higher than the estimated historical average subsidy of US$ 2.69 per capita per year (or US$ 0.63 per

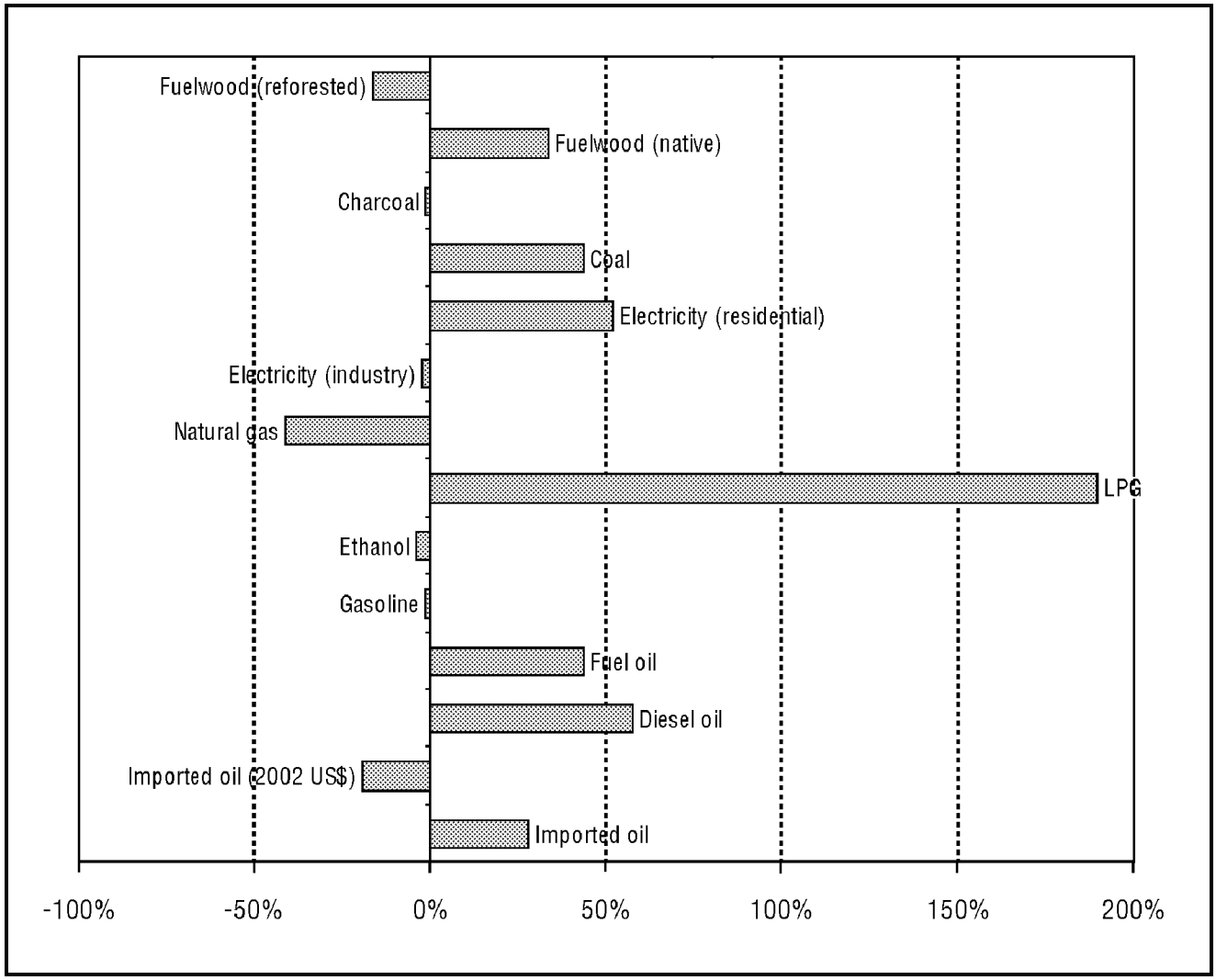

Figure 6. Price (corrected to 2002 US$) variation during the period 1987-2002 [MME, 2003]

person-year, if corrected for inflation).

Electricity and natural gas are substitutes for LPG where there is infrastructure. This is not the case for isolated communities in the Amazon and other rural regions, as well as in many urban slums lacking basic amenities[11]. Such populations must be protected by effective policy measures.

It is necessary to guarantee that the already established LPG network continues operating and expands to the most needy. In this sense, subsidies cannot be considered economically, socially or environmentally harmful.

8. Lessons learned and perspectives obtained

The benefits from LPG are not only social, but environmental. This "portable" energy option has a critical role in preventing deforestation in the "hot spots", where the management of native forests is difficult and the energy demand pressure is high.

With a refining capacity of 250,000 t (1.86 million barrels) of petroleum per day, Brazil is responsible for only 2.2 % of the world total. Although the country is a strong candidate to receive investments in this sector, imports of LPG are likely to remain for a long time. The provision of the gas from an increased refining capacity, with more surpluses of gasoline and fuel oil, is not cost-attractive. An alternative in the medium term, starting from 2008, is a gas-to-liquids (GTL) plant, allowing the commercial utilization of a larger share of the available natural gas and the production of 34,000 t per day of synthetic oil derivatives, at a challenging cost of US$ 5 billion [Bandeira, 2003][12].

In order to minimize the impact of imports on the external debt, to maximize the use of the national refineries, to add value to oil exports, and to reduce risks of supply deficits, rationalization projects are still necessary, especially for LPG.

A coordinated energy policy should, therefore:

- provide natural gas and electricity to LPG users who can afford it;
- develop alternatives to LPG, such as an infrastructure for producing liquefied natural gas (LNG) for urban areas and reforested fuelwood plus improved cookstoves;
- increase refining capacity to produce more LPG without significant surpluses of co-products to be exported at low prices (the case of gasoline);
- identify, between the refiner and the distributor, where the profit margins are too high – and correct the discrepancies;

- preserve the purchasing parities of the *Auxilio Gas* bonds and/or maintain the subsidies to the fuel for low-income families; and
- provide technological alternatives for better use of fuelwood and charcoal, such as efficient cookstoves.

Almost half of the energy produced in a LPG stove is wasted, heating air and the stove parts but not the food. Such losses are higher in homes than in industrial equipment. ANP, the National Petroleum Agency, started an efficiency program focusing on three aspects: fuel, equipment, and usage. For the first, fuel standards are to be revised soon. Equipment, the second issue, depends upon the project, materials and manufacturing of stoves and heaters. A labelling program was jointly conducted by manufacturing associations (ABINEE and ELETROS), the official standardization body (INMETRO), as well as the Ministry of Mines and Energy's institutions (MME, CONPET and ANP), achieving efficiency gains of up to 13 %, or a potential fuel-cost saving of US$ 100 million per year in the residential sector alone. Finally, rational usage is certainly an important aspect, bringing about fuel savings of 20 % or more [Nogueira, 2004]. The two last issues depend strongly on campaigns to improve consumer awareness, to buy better products, and to use them wisely. Such initiatives are part of the national legislation establishing energy conservation and rational usage (Law 10,925/2001). In the future, initiatives like these should be extended to other LPG-burning equipment. ■

Acknowledgement

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Notes

1. If the refinery output mix were to be adjusted to meet LPG and diesel oil demand, a great excess of gasoline and fuel oil would be produced. Exporting gasoline and fuel oil is generally not economically attractive.
2. The net external trade balance went from a positive US$ 470 million in 1989 to a negative US$ 2.6 billion in 1997. The main contributors to this were diesel oil for transportation and decentralized power generation, followed by LPG for domestic consumption [ANP, 1998].
3. LPG use entails emissions of CO_2, the main greenhouse gas, but LPG use can be considered more sustainable than fuelwood from deforestation. Besides, taking into account household use and energy access, such sustainability is to be considered for the medium term, before substitution by other better fuels in terms of renewability, existing reserves and less harmful aggregate emissions.
4. The author (Patusco) is responsible for the methodology utilized in the National Balance. Considered efficiencies of LPG, charcoal and fuelwood cookstoves are respectively 45 %, 9 % and 4 %. In 2002, consumption for each household having specific cookstoves was 0.125 tonnes (t) of LPG per year, 0.360 t charcoal/year and 10.1 m^3 of fuelwood/year.
5. The LPG and electricity consumption were 1791 MJ/capita and 2725 MJ/capita, respectively [Kamimura, 2002].
6. For further discussion on these issues, see Margulis [2003].
7. Pernambuco, Paraíba, Rio Grande do Norte and Ceará.
8. This was R$ 200 million, which is about the amount spent to subsidize diesel oil [Tribuna do Norte, 2000].
9. Lei do Petróleo, Law 9478/1997.
10. The National Energy Policy Council (CNPE – Conselho Nacional de Política Energética) was created to develop and propose specific sectoral measures, and the National Oil Agency *(ANP – Agência Nacional do Petróleo),* reporting to the Ministry of Mines and Energy *(MME – Ministério das Minas e Energia)* was created to inspect and regulate the sector's activities. Both institutions started operating in 1998.
11. However, in slums it is not uncommon to find clandestine use of electricity from the grid, for many purposes including cooking and water-heating.
12. This alternative was suggested to the National Chamber of Deputies in the referenced report.

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Appendix A. LPG balance in Brazil

The National Petroleum Agency divided Brazil's territory into four distribution regions: North/Northeast, Southeast (São Paulo state) + Midwest (including Tocantins state), Southeast (Rio de Janeiro, Espírito Santo and Minas Gerais states) and South, based on the refineries' areas of influence. The following table presents the balance and forecasts for LPG in Brazil.

	Region	2002*	2003	2004	2005	2006	2007
Demand (kt)	Brazil	6662	6196	6134	6134	6220	6307
Production (kt)		4899	5310	5562	5653	5747	5904
Imports (kt)		1763	886	572	481	473	403
Consumption (kt)	North	324	301	298	298	302	307
	Northeast	1347	1253	1240	1240	1258	1275
	Southeast (RJ/ES/MG)	1283	1193	1181	1181	1198	1214
	Southeast-(SP) + Midwest	2567	2387	2363	2363	2396	2430
	South	1141	1061	1051	1051	1066	1080
	Brazil	6662	6196	6134	6134	6220	6307
Production (kt)	North	414	476	552	619	626	626
	Northeast	990	1018	1127	1237	1284	1331
	Southeast (RJ/ES/MG)	1079	1275	1415	1111	1146	1201
	Southeast-(SP) + Midwest	1714	1796	1755	1775	1780	1835
	South	702	745	713	911	911	911
	Brazil	4899	5310	5562	5653	5747	5904
Production by installation (kt)	Refineries Petrobras	4099	4312	4436	4447	4514	4664
	NGPUs Petrobras	729	839	959	1039	1066	1073
	Other (six) Petrobras	7	16	16	16	16	16
	Total Petrobras	4835	5167	5411	5502	5596	5753
	Total other producers	64	143	151	151	151	151
	Total (Petrobras + other producers)	4899	5310	5562	5653	5747	5904
Consumption (t/d)	North + Northeast	4579	4258	4216	4216	4275	4335
	Southeast (RJ/ES/MG)	3514	3268	3236	3236	3281	3327
	Southeast (SP) + Midwest	7032	6539	6474	6474	6565	6656
	South	3127	2908	2879	2879	2919	2960
	Brazil	18252	16974	16805	16805	17040	17278
Tankage (t)	North + Northeast	140999	140999	140999	140999	140999	140999
	Southeast (RJ/ES/MG)	45918	45918	45918	45918	45918	45918
	Southeast (SP) + Midwest	144620	144620	144620	144620	144620	144620
	South	44429	44429	44429	44429	44429	44429
	Brazil	375966	375966	375966	375966	375966	375966
Tankage/consumption (d)	North + Northeast	30.8	33.1	33.4	33.4	33	32.5
	Southeast (RJ/ES/MG)	13.1	14	14.2	14.2	14	13.8
	Southeast (SP) + Midwest	20.6	22.1	22.3	22.3	22	21.7
	South	14.2	15.3	15.4	15.4	15.2	15
	Brazil	20.6	22.1	22.4	22.4	22.1	21.8

Source: ANP, 2003