3. BRAZIL

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3.1. Introduction

This chapter represents Brazil's contribution to the Indicators for Sustainable Energy Development (ISED) programme coordinated by the International Atomic Energy Agency (IAEA). The ISED programme is designed to select particular subsets of sustainable development indicators most relevant to a country's energy priorities, and then to apply these indicators in analyses of current and potential future energy systems and policies.

This chapter presents the final report and follows the outline proposed for each county team included in the ISED project. The report is more analytical than previous progress reports prepared by Brazil, and includes some updated data. Moreover, it was developed in parallel with the study *Brazil: A Country Profile on Sustainable Energy Development* (IAEA, et al., 2006), which incorporated some of the indicators from the ISED project and supported some of the analysis undertaken in this study. Thus, it should be stressed that the coordination of this study coincides with the coordination of the Brazilian energy country profile study, and both were performed at the Federal University of Rio de Janeiro, in conjunction with the IAEA.

The rest of the chapter is organised into six major sections, as follows: (3.2) an overview of the Brazilian energy sector[1], (3.3) a review of the energy statistical data capability of the country, (3.4) the definition of major energy priority areas for the national context, (3.5) the implementation of the ISED framework for Brazil, (3.6) identification of response actions and energy policies in priority, and (3.7) the conclusions and recommendations of the report.

3.2. Overview of the Energy Sector[2]

This overview of the Brazilian energy sector discusses three principal topics. First, the Brazilian energy balance data indicators are presented and discussed. Second, selected indirect driving forces and states of the economic dimension of Brazilian sustainable energy development are then analysed. Finally, select driving forces and the states of other dimensions for sustainable energy development also are analysed.

It should be emphasized that the identification of each ISED Indicator used by the Brazilian Team is provided in the tables or charts. The selection of these indicators is discussed in Section 3.2, as well as the potential use of additional indicators to the original ISED set, whose aim is to provide information on specific features of the Brazilian energy system. Within this section, these additional indicators are identified by numbers and also by the label "additional".

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[1] The first section is based upon previously selected indicators, chosen according to the ISED methodology.

[2] Besides the update of some indicators and some analysis introduced by the Brazilian team, this section is based on two main sources: the first year- report of the ISED Project (Schaeffer et al., 2002) and Chapter 2 from the study *Brazil: a country profile on sustainable energy development*, written by Szklo and Cunha (IAEA et a., 2006).

3.2.1. Brazilian energy balance - general overview

During the previous two decades, Brazil's Energy Balance reflected considerable changes in the energy sector, economy and government policies (see Table 3.1) During the 1980s, the share of renewable energy sources in the Total Primary Energy Supply (TPES) increased owing to economic policies adopted during the 1970s, which promoted indigenous energy alternatives such as hydropower and biomass to replace oil imports. In addition, renewable replaced non-renewable biomass, due to the increased use of modern energy sources in the industrial sector (black liquor in the pulp and paper segment, for instance) and the urbanization of the country.[3]

TABLE 3.1. BRAZIL'S ENERGY BALANCE IN PJ – ISED #11

Domestic	1980	1985	1990	1995	2000	2001	2002
Coal and coal products	104	147	80	85	109	91	84
Gas	46	123	181	227	348	355	427
Oil and oil products	389	1,168	1,348	1,481	2,666	2,793	3,143
Hydropower	464	642	744	914	1,095	964	1,025
Nuclear	0	32	21	24	58	137	133
Biomass - Renewable	894	1,265	1,293	1,467	1,584	1,669	1,800
Biomass -non renewable	833	961	733	510	399	417	450
Total Domestic	2,730	4,340	4,401	4,709	6,259	6,427	7,061
Net Imports							
Coal and coal products	161	262	343	431	456	449	463
Gas	0	0	0	0	81	170	194
Oil and oil products	1,877	891	1,136	1,352	1,041	801	360
Electricity	-1	7	95	127	159	136	132
Biomass	0	0	31	65	2	3	0
Total Imports	2,037	1,160	1,606	1,976	1,740	1,559	1,149
Stock Variation							
Coal and coal products	-12	20	-9	0	2	18	-2
Oil and oil products	63	3	-80	106	-85	87	65
Biomass	6	-53	-4	0	40	9	4
Total Stock var.	57	-30	-93	105	-43	114	67
TPES (Domestic+Imp+Stck)							
Coal and coal products	253	430	415	517	568	559	544
Gas	46	123	181	227	429	525	621
Oil and oil products	2,329	2,062	2,404	2,939	3,623	3,681	3,568
Hydropower	464	642	744	914	1,095	964	1,025
Nuclear	0	32	21	24	58	137	133
Biomass	1,733	2,174	2,022	1,977	2,022	2,096	2,254
Electricity (imports)	-1	7	95	127	159	136	132
TOTAL TPES	4,824	5,471	5,882	6,725	7,954	8,097	8,276

Source: MME, 2003

[3] Please note that, throughout this report, the distinction between modern and traditional biomass sources proposed by Goldemberg and Coelho (2004) will be employed. According to these authors, "biomass produced in a sustainable way—the so-called modern biomass—excludes traditional uses of biomass such as fuelwood and includes electricity generation and heat production, as well as transportation fuels, from agricultural and forest residues and solid waste." On the other hand, ''traditional biomass'' is produced in an unsustainable way and it is used as a non-commercial source—usually with very low efficiencies for cooking in many countries".

Notes: The estimated fraction of combustible non-renewable biomass supplied in Brazil over the past two decades was based on Schechtman et al. (1999), ABRACAVE (2002), and Aquino (1999). However, the fragility of the primary data on this matter is still quite considerable, particularly owing to the historically significant use of fuelwood by the industrial sectors (to produce charcoal consumed largely by steel mills) and the residential sector (for cooking, particularly in rural areas).

TPES grew on average 2.5 % p. a. between 1980 and 2001, a rate slightly higher than the economic growth (2.0 % p. a.). For the same period, natural gas and hydropower increased steadily. The share of oil decreased in the first half of the 1980s, but since the oil counter shock in 1986, it has been recovering its market share; coal increased merely owing to the demand pull of the metallurgical sector; and biomass was pushed up through use of modern sources in the industrial sector and the transportation sector (ethanol-fuelled cars), and fuelwood substitution occurred mainly in the household sector (see Figure 3.1).

Actually, fuelwood as energy biomass in Brazil meets two main demands: small-scale decentralized use in the residential sector (an average of 32% of the domestic supply of fuelwood was channelled to meet these uses from 1980 through 2000)[4], and that of charcoal-burners.

On average, one half of the fuelwood used in the residential sector is gathered in the form of secondary growth such as scrubwood, twigs and branches (Schechtman et al., 1998), and consequently does not impose deforestation pressures (non-commercial woody biomass circuit)[5].

Fuelwood use in charcoal-burners (averaging out at 40% of the allocation of the fuelwood supply in Brazil from 1980 through 2000) is higher and more concentrated than that of the residential sector. In some areas, such as Amazonia, this contributes to deforestation pressures (Aquino, 1999). In other states, and for much of Brazil's steel industry output in Minas Gerais State, the use of energy-based biomass does not necessarily impose deforestation pressures, as much of the charcoal consumed is either renewable or produced from planted forests (ABRACAVE, 2002).

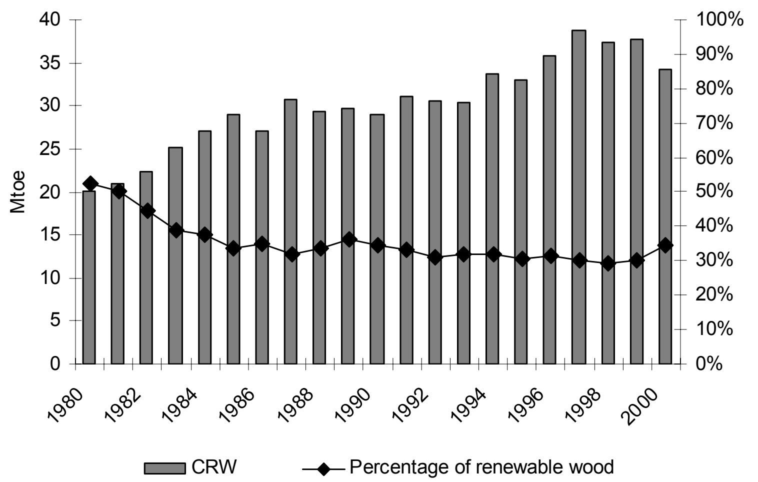

Figure 3.1. CRW indigenous production and percentage of renewable wood (1980-2000) –ISED # 17
Source: Based on MME (2001), Schechtman et al (1998), ABRACAVE (2002) and Aquino (1999).

Consequently, the use of biomass for energy purposes is not the main driving force behind the deforestation of native forests in Brazil (see Table 3.2), although it exists and therefore can be measured. Actually, in general terms, the expansion of commercial agriculture and cattle ranching − often fuelled by government incentives or by colonization and settlement policies − represents the main cause of deforestation, which is normally associated with predatory logging (Camargo, 2002). More recently, some specialists have also indicated the problem of export-oriented enterprises moving into the Amazon and Cerrado regions where they log, produce beef, and grow soybeans, all with detrimental impacts on the forests (Rodrigues, 2002).

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[4] As discussed in this document through the use of other ISED, these demands have been shrinking over the past two decades.

[5] The exception to this rule is the urban sprawl around large towns and cities in Northern Brazil, where there is an established market for fuelwood and charcoal, in addition to easily-available wood from the Amazon Rainforest (Aquino, 1999).

TABLE 3.2. GROSS DEFORESTATION FROM 1978 TO AUGUST 2000 IN THE AMAZONIAN BIOMES(1) ISED #41

Years	Extent (km^2) (2)	Period	Mean rate 1 (km^2/year)	Mean rate 2 (%/year)
Jan/1978	152,200	77/88(3)	21,130	0.54
Apr/1988	377,500	88/89	17,860	0.48
Aug/1989	401,400	89/90	13,810	0.37
Aug/1990	415,200	90/91	11,130	0.30
Aug/1991	426,400	91/92	13,786	0.38
Aug/1992	440,186	92/94(4)	14,896	0.41
Aug/1994	469,978	94/95	29,059	0.80
Aug/1995	497,055	95/96	18,161	0.51
Aug/1996	517,069	96/97	13,227	0.37
Aug/1997	532,086	97/98	17,383	0.51
Aug/1998	551,782	98/99	17,259	0.49
Aug/1999	569,269	99/00	18,226	0.52
Aug/2000	587,727	00/01	15,787	

Source: INPE (2002)
Notes: (1) Relative to the area of remaining forest formations. The figures are related to all causes of deforestation in the Amazon. (2) Includes old deforestation. (3) Decade Mean. (4) Biennium Mean.

A final point related to the impact of non-renewable energy biomass on deforestation in Brazil is its considerable diversity of biomes. This makes it almost impossible to estimate an average value for the ratio between the energy content of non-renewable energy biomass consumed in Brazil, for which estimates exist[6], and the deforestation that this implies. Brazil has some 5.5 million km^2 of native forests, two-thirds of which are located in Amazonia and the remainder (in descending order) in the Cerrado savannas of the Center-West[7], the Atlantic Rainforest, the Caatinga scrublands and other associated ecosystems[8].

In addition to these natural forests, there are some 64,000 km^2 of tree plantations, used mainly to produce pulp and paper, charcoal, wood and rubber, located largely in Espírito Santo, Minas Gerais, Bahia, Paraná and São Paulo States (Schaeffer et al., 2002).

Still regarding the Brazilian Energy Balance, Brazil's energy dependence decreased over the last two decades, mostly owing to government programs on oil products substitution and national oil production expansion (Figure 3.2). The focus was on replacing imported oil because it is the most important energy source weighting the trade balance. Oil dependence decreased from 81% to 28% between 1980 and 2000. However, coal imports moved in the opposite direction, increasing mainly owing to the metallurgical industry needs, and a small fraction of total electricity began to be imported when the Itaipu bi-national power plant was started-up[9]. Natural gas imports were initiated in 1999.

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[6] See Schechtman et al. (1998).

[7] The *cerrado* savanna ecosystem occurs on the Central Brazilian Plateau (Planalto), as well as parts of Amazonia and the Northeast. These savannas consist largely of low-growing, widely-spaced trees with grassy ground cover. The *cerrado* savannas still lack adequate scientific surveys on the development of natural plant cover, and are today threatened by the expansion of agriculture growing grain crops for export.

[8] The *caatinga* scrublands are rated as the only ecosystem that is exclusively Brazilian. Home to 932 known plant species, of which 380 are endemic, this heterogeneous biome also ranks among the ecosystems most altered by human activities.

[9] In 1975, the bi-national Itaipu hydroelectric power plant began to be built, at the border between Brazil and Paraguay, in the south of the country. The plant was inaugurated in October 1984, while the final installation of 12,600 MW was completed in 1991 (the water intake of one single 715 MW Francis-turbine is 700 m^3/s, its weighted efficiency is 93.8%). Paraguay delivers to Brazil most of the power generated at 50 Hz (frequencies in Brazil and Paraguay are different, and Paraguay consumes less than 4% of the electricity generated by Itaipu). Thus, it was decided to build a composite transmission system, including an Extra High Voltage system (AC) for 6,300 MW (Brazilian part at 60 Hz, transmitted by 891 km at 750 kV) and a High Voltage system (DC) for about 6,000 MW of the 50 Hz part (imported from Paraguay, at ± 500 kV, and converted back into AC).

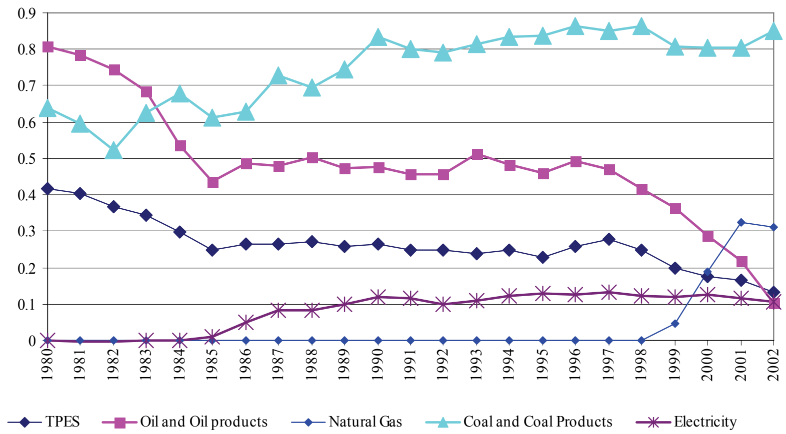

Figure 3.2. Energy net imports dependence ISED # 18
Source: MME (2003).
Note: The oil net imports used to calculate Brazil's dependence on oil include both imported crude and oil products (Schaeffer et al, 2002).

The Brazilian final energy use evolution shows the increase of non-renewable energy sources in the energy mix during the 1990s (see Table 3.3). The market share of electricity rose, but that of biomass remained the same. In addition, since the 1990s, charcoal has been replaced by coal or coke and neat ethanol by gasoline, although the proportion of anhydrous ethanol in the gasohol mixture remained roughly the same, hovering between 20 and 26% (MME, 2002a). In the case of natural gas, use is still low, given the infant stage of the industry. Nevertheless, growth of this energy source in Brazil's mix is expected in the near future, mostly by increasing its use in thermal-power plants and industrial heat generators. Some increase of natural gas household use is also expected in major cities of the Southeast. Figure 3.3 shows final energy use of the Brazilian economy by sector.

TABLE 3.3. FINAL ENERGY CONSUMPTION IN PJ – ISED # 11

Energy Sources	1980	1985	1990	1995	2000	2001	2002
Oil	2,131	1,898	2,241	2,747	3,352	3,331	3,291
Coal	184	315	303	394	439	426	451
Gas	30	65	102	130	215	255	320
Electricity	427	602	759	923	1,155	1,074	1,114
Fuelwood	1,147	1,085	893	919	1,024	1,113	1,203
Ethanol	88	242	329	389	270	253	262
Charcoal	179	259	257	206	201	184	193
				Sectors			
Industrial	1,583	1,710	1,806	2,138	2,561	2,574	2,723
Commercial & public	124	150	196	256	344	329	342
Transportation	1,116	1,192	1,441	1,807	1,983	2,000	2,028
Residential	879	777	758	760	866	843	866
Agriculture	243	255	253	297	305	323	337
Sub-total	3,945	4,084	4,454	5,258	6,059	6,069	6,296
Non energy / feedstocks	241	382	430	450	598	567	538
TOTAL	4,186	4,466	4,884	5,708	6,657	6,636	6,834

Source: MME, 2003.
Note: According to the authors' estimates, the renewable biomass fraction of the total biomass use increased from 56% in 1980 to around 80% in 2000.

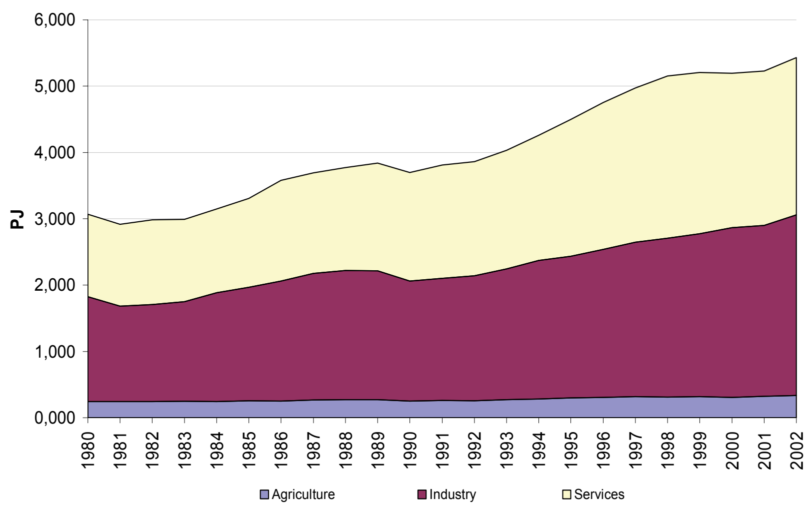

Figure 3.3. Final energy use of the Brazilian economy by sector –ISED #11
Source: MME (2003).

With regard to the sectoral analysis, the final energy consumption on the residential sector remained almost unchanged (average rate of -0.2%p.a.) between 1980 and 2001. The reduction of traditional biomass use was compensated by an increase in more efficient LPG and electricity use, due to the trend toward urbanization (see Figure 3.4, which derives from Indicator #1 of the ISED methodology).

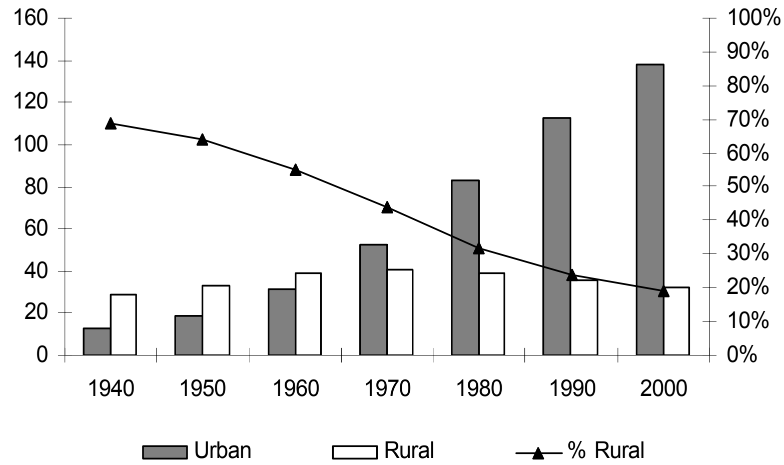

Figure 3.4. Population (million inhabitants) – ISED #1
Source: IPEADATA 2003.

In turn, the commercial and public sectors showed an average growth rate of 4.9% p.a., owing to the growing share of these sectors in the Brazilian GDP and their modernisation, which resulted in larger electricity consumers, such as big hospitals, hotels and shopping centres (Figure 3.5).[10]

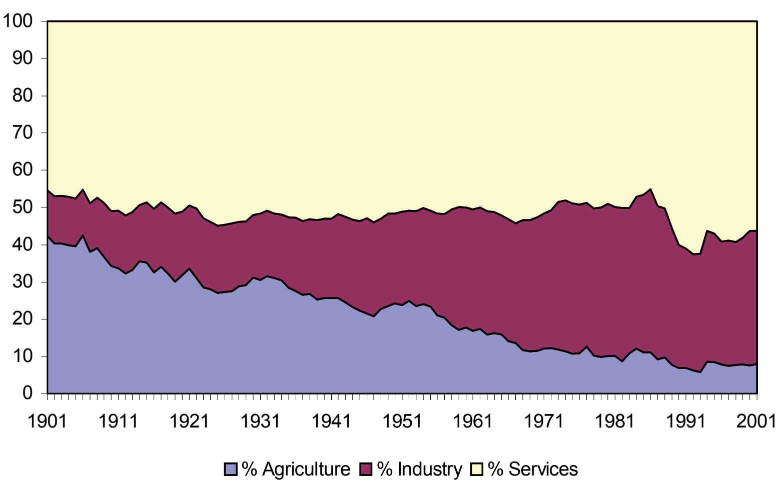

Figure 3.5. GDP's Share – ISED # 4
Source: IPEADATA, 2003.

The final energy consumption average growth rate of the transportation sector was also higher than that observed in the overall economy (respectively, 3.1% and 2.6% p.a.) between 1980 and 2001. This was due not only to activity effects (the increase of passenger and freight transportation), but also to the growth in road transport and the increased use of private cars in Brazil (see Table 3.4 and Table 3.5, which refer to Indicators #5 and Indicators #6 of the ISED methodology).

[10] See also section 3.4 containing the implementation of the ISED indicators for more information about the economic dimension and the direct and indirect driving forces of the Brazilian energy development.

TABLE 3.4. EVOLUTION OF TOTAL DISTANCE TRAVELLED BY PASSENGERS (PASSENGER ACTIVITY) IN BRAZIL – ISED #5

(pkm) (per capita)	Air	Rail	Road	Total
1980	78.60	114.26	3,374.33	3,567.19
1985	81.46	139.25	3,694.88	3,915.59
1990	102.76	123.09	4,115.03	4,340.88
1995	100.22	96.33	4,691.62	4,888.16
2000	121.10	n.a.	5,189.41	5,310.51

Source: GEIPOT, 2000
Notes: Passenger activity by aquatic mode of transportation is not included (not reported to GEIPOT). Rail includes subway and train. The same applies to passenger activity by rail in 2000. "n.a." means not available.

TABLE 3.5. EVOLUTION OF TOTAL FREIGHT TRANSPORT ACTIVITY PER CAPITA IN BRAZIL – ISED #6

(t.km) (per capita)	Air	Inland waters	Pipeline	Rail	Road	Total
1980	8.39	392.24	98.09	709.65	1,714.48	2,922.85
1985	9.91	577.72	131.50	741.83	1,686.08	3,147.06
1990	11.94	695.58	141.63	815.55	2,122.24	3,786.94
1995	12.28	444.04	151.61	858.15	2,383.45	3,849.54
2000	14.29	607.66	195.40	914.47	2,652.88	4,384.71

Source: GEIPOT, 2000
Notes: Inland water transportation includes coastal water transportation.

Also important in the transportation sector is the use of ethanol either as an additive to the gasoline or as the fuel for hydrated ethanol fuelled-cars. Automotive ethanol is specific and important within the context of energy used for automotive purposes in Brazil. There have been three ways of using ethanol produced from sugar-cane (since the introduction of the Alcohol Incentive Program in Brazil, known as PROALCOOL, during the mid-1970s): fuelling motors running only on alcohol in its hydrated form,[11] fuelling flex-fuel motors running on variable mixtures of hydrated alcohol and gasoline, and fuelling gasoline motors, as a gasoline additive, in its anhydrous form (at 99.6 GL [Gay Lussac]) in proportions that have varied over the past two decades, as shown by Figure 3.6.[12]

[11] Ethanol has a number of advantages over gasoline in terms of engine and vehicle efficiency. First, compression ratios as high as 12:1 can be used; second, the heat of alcohol vaporization per unit of fuel energy is six to eight times that of gasoline; third, it is possible to use leaner air-fuel mixtures with fuel alcohol (reducing NOx emissions, for instance).

[12] Subsidies for ethanol production and use were justified based on the positive economic, social, and environmental impacts of this program. Ethanol produced from sugarcane improves Brazil's balance of payments, eases unemployment and urbanization pressures, and provides both local and global environmental benefits. Ethanol production was stimulated through a combination of policies including: low-interest loans for the construction of ethanol distilleries, guaranteed ethanol purchases by the state-owned oil company at prices rated as adequate for guaranteeing ethanol producers reasonable profits; neat ethanol priced as competitive if not slightly favourable to the gasoline-ethanol blend; and sales tax incentives during the 1980s that encouraged purchases of neat ethanol vehicles.

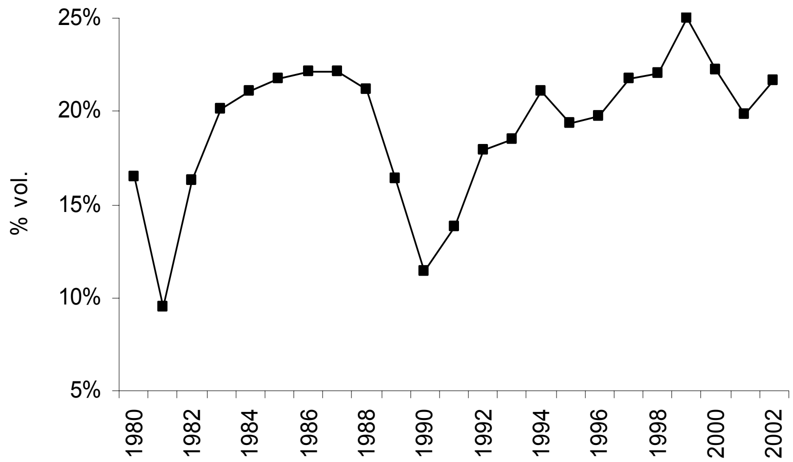

Figure 3.6. Anhydrous Ethanol Added to the Gasoline-Ethanol Blend (gasohol) – Additional ISED #11.4
Source: MME, 2001.

As mentioned earlier, the use of hydrated ethanol depends on the ethanol-fuelled fleet. Among other reasons, this explains why an indicator for the composition of the country's light vehicles fleet is so important. Figure 3.7 below displays the evolution of the light fleet by fuel (except for natural gas) in percentage.

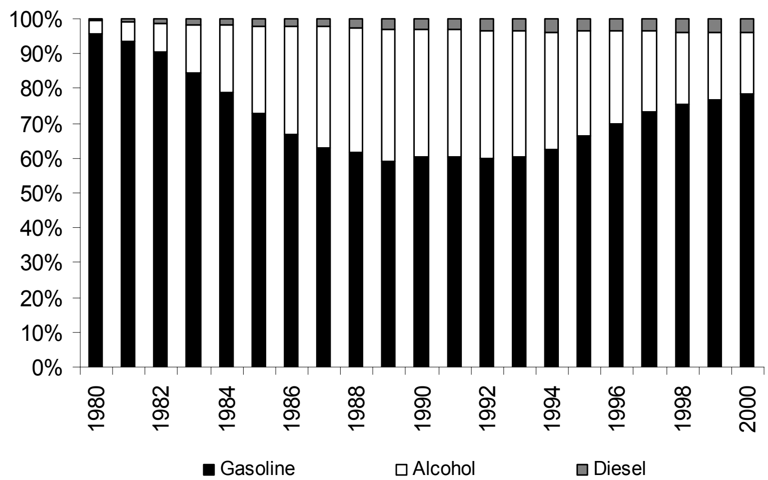

Figure 3.7. Shares of light fleet by fuel in Brazil – Additional ISED #11.5
Source: GEIPOT, 2000.
Note: Natural Gas (converted) vehicles are not reported separately from gasoline vehicles, but the natural gas fleet is not significant.

As noted, as of 2004, ethanol is used mainly as an additive for gasoline (24-26% in a volumetric proportion), i.e. anhydrous ethanol, mainly for local environmental reasons. The other alternative − the use of hydrated ethanol in engines solely fuelled by ethanol – lost ground through 2002. Actually, Brazil's ethanol incentive program for Otto Cycle engines automotive vehicles was extraordinarily successful until the 1990s, with new cars fuelled by ethanol accounting for more than 90% of light vehicles' sales in the 1985-90 period. However, a steep drop was noted in ethanol-fuelled automobiles over the following few years, owing mainly to three reasons: 1) a gradual increase in the price of ethanol, which is a trend that began to reverse after 2000; 2) incentives to produce 1-litre engine gasoline fuelled-automobiles at lower tax rates; and 3) unreliable ethanol supplies that culminated in the need to import ethanol/methanol to meet

demands.[13] As a result of the combination of these factors, the sales of cars fuelled by ethanol fell to almost zero, dropping to under 0.5% of new automobile sales by the late 1990s (Poole et al, 1998).[14] The fleet of automobiles in 2003 was fuelled almost solely by gasoline, with some 300,000 to 400,000 ethanol-fuelled cars scrapped each year.

Nevertheless, since 2003 flex-fuel vehicles began to be produced in the Brazilian market. These light-vehicles are capable of consuming a mixture of hydrated ethanol and gasoline at any proportion, basically because of its sophisticated electronic control of emissions, air-fuel composition and ignition delay time. In 2003, the flex fuel sales reached 48,178 units. By October of 2004, the annual sales of flex fuel vehicles reached 249,116 units, accounting for 24.1% of the national sales. Some studies forecast that the share of this alternative vehicle in the total light vehicle sale will reach 70% in ten years (Schaeffer et al., 2004).

In the last decades, electricity use increased tremendously, reaching 331 terawatt-hours in 2000 (Table 3.6). The key drivers of this growth were: the large ongoing share of electricity-intensive industries[15] in Brazil's industrial output since the 1980s; the country's urbanization allied with population growth, which changed household consumption patterns; modernization of the agricultural sector;[16] and low electricity prices, especially during the 1980s.[17]

Industrial sector power demand rose steeply during the 1970s, reaching 56% of total electricity use by 1980. During the 1980s, growth rates slowed, averaging only 5.11% p.a., compared to 14% experienced during the 1970s. The 1990's saw the restructuring of Brazil's industrial sector, with a slower expansion of electricity-intensive sectors resulting in an average annual growth of 2.64% in electricity use by this sector. Yet, as of 2001, the industrial sector still accounts for 44% of the country's electricity use, largely as a result of the use of electricity-intensive sectors.

TABLE 3.6. ELECTRICITY USE BY SECTOR, 1980- 2002, IN TERAWATT HOURS – ADDITIONAL INDICATOR

Sectors	1980	1985	1990	1995	2000	2001	2002	GR 1990-2000 (%)	GR 2000-01 (%)	GR 2001-02 (%)
Residential	23	33	49	64	84	74	73	6	-12	-1
Commercial	14	18	24	32	47	45	46	7	-6	2
Industrial	68	96	112	127	147	139	148	3	-5	7
Others	17	26	33	42	54	52	54	5	-4	5
Brazil	123	173	218	265	331	309	321	4	-7	4

Source: MME, 2003.
Note: GR means average annual growth rate.

Regarding the power generation mix (Table 3.7), as of today, three different electric systems supply the five macro political regions of the country (north, northeast, mid-west, southeast and south). The largest interconnected power transmission system, which includes the Southeast, South, and Mid-West regions, accounted for more than 70% of Brazilian total installed capacity in 2000. It includes the hydroelectric power plant of Itaipu, and the two nuclear power plants currently in operation in Brazil: Angra I, with 657 MW installed, and Angra II with 1,309 MW. The second grid system connects the north and northeast

[13] The Brazilian Government cut the price it paid to ethanol producers throughout the 1980s, particularly after the world oil price collapse in 1986. In addition, sugar prices spiked in the international market, where Brazil was the most important player. Consequently, fuel producers stopped increasing ethanol production by the late 1980s. This in turn resulted in ethanol shortages and the need to import ethanol and methanol for a short period of time in the 1989-1990 period.

[14] More recently, this trend seems to be shifting, with some 5% of the new cars sold in Brazil during the first half of 2002 consisting of vehicles fuelled by hydrated ethanol.

[15] Energy-intensive industrial sectors include: non-metallic minerals, iron and steel, non-ferrous metals, pulp and paper, and chemicals (although chemicals include non-energy intensive segments, such as fine chemicals, additives, advanced plastics, etc.).

[16] Since 1979, the Brazilian government has been promoting the modernization of the agricultural sector, focusing mainly on two different sets of goods: export oriented primary crops and fruits, and biomass for energy purposes. In addition, the Rural Electrification Program launched in 1999 also affected the use of electricity by medium and small Brazilian farms.

[17] Brazil's government took actions designed to curb inflation, imposing tight controls on tariff levels. This stimulated industrial and household electricity consumption.

regions, accounting for almost 25% of Brazilian total installed capacity. Finally, the country's electric power system includes small, independent grids that operate remotely, largely in the northern region. These isolated systems account for less than 5% of Brazil’s electricity market and are based mainly on thermal power plants (SIESE, 2002). The interconnected hydropower systems have been complemented by thermal-power plants fired by coal, oil products and even biomass sources such as sugarcane bagasse and black liquor. An increase in the share held by thermal-power generation fuelled by natural gas is expected in Brazil. Designed to create a market for this energy source imported from Bolivia while simultaneously diversifying Brazil's energy mix, the use of natural gas to generate electricity began to gain force from 2002 onwards, with the start-up of operations of gas-fired thermal-power plants.

TABLE 3.7. ELECTRICITY GENERATION MIX (TWH) – ISED #11

	1980	1985	1990	1995	2000	2001	2002
PUBLIC SERVICE PLANTS							
Hydro	126.1	175.3	203.6	250.5	298.6	262.7	278.7
Fuel oil	1.6	1.2	0.9	1.3	6.2	6.1	3.7
Diesel oil	0.9	1.1	1.5	2.7	4.1	4.0	4.3
Natural gas	0.0	0.0	0.0	0.0	1.6	6.9	9.8
Nuclear	0.0	3.4	2.2	2.5	6.1	14.3	13.8
Coal	2.5	3.3	2.7	3.7	7.5	7.4	5.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PUBLIC	131.0	184.4	210.9	260.7	323.9	301.3	315.3
SELF PRODUCERS							
Hydro	2.8	3.0	3.1	3.5	5.8	5.2	6.3
Fuel oil	2.5	1.3	2.0	2.1	1.8	2.0	1.7
Diesel oil	0.2	0.3	0.5	0.4	1.5	2.1	1.6
Natural gas	0.0	0.0	0.3	0.6	2.5	3.0	3.4
Coal	0.3	0.6	0.5	0.6	0.8	0.9	0.9
Biomass	1.8	3.0	3.6	5.4	7.4	8.4	9.6
Other primary	0.7	1.1	1.7	1.4	3.5	3.9	4.2
Other secondary	0.0	0.0	0.3	1.1	1.7	1.8	1.7
TOTAL SELF PR	8.4	9.3	11.9	14.9	25.0	27.2	29.3
PUBLIC SERVICE + SELF PRODUCERS							
Hydro	128.9	178.4	206.7	253.9	304.4	267.9	285.0
Fuel oil	4.1	2.5	2.9	3.4	8.0	8.0	5.4
Diesel oil	1.1	1.4	2.0	3.1	5.6	6.1	5.8
Natural gas	0.0	0.0	0.3	0.6	4.1	10.0	13.2
Nuclear	0.0	3.4	2.2	2.5	6.1	14.3	13.8
Coal	2.8	4.0	3.3	4.3	8.3	8.2	6.0
Biomass	1.8	3.0	3.6	5.4	7.4	8.4	9.6
Other primary	0.7	1.1	1.7	1.4	3.5	3.9	4.2
Other secondary	0.0	0.0	0.3	1.1	1.7	1.8	1.7
TOTAL GENERATION	139.4	193.7	222.8	275.6	348.9	328.5	344.7

Source: MME 2003.
Note: Non-combustible renewables are almost null in the period of analysis.

Although the power system is classified as “hydro-thermal”, there is a strong predominance of hydroelectric plants distributed in 12 different hydrographic basins located in different areas of the country. Moreover, there is still considerable hydropower potential unused in Brazil (almost 200 GW in 2000), so that hydropower is expected to keep its significant role in Brazil's power generation scene over the next few decades (Table 3.8). However, this potential is scattered unevenly throughout the country: only 11% lies in the Southeast, which is the region with the highest electricity consumption, while 54% is in the North, resulting in higher electricity transmission costs as well as environmental constraints on more effective use of Brazil's energy “stocks”. Besides, the potential for retrofitting the existing Brazilian hydro plants that are more than 20 years old (32 GW or 42% of the total power installed capacity in 2001) hovers between 1 and 8 GW, depending on how much is invested (Filho et al., 2003).

TABLE 3.8. POTENTIAL CAPACITY FOR HYDROPOWER GENERATION ISED #35

Region	TOTAL (MW)	Installed Capacity in 2000 (MW)	Installed Capacity / Total Potential
North	112,495	4,867	4.3%
Northeast	26,710	10,143	38.0%
Southeast	42,776	21,204	49.6%
Mid-West	36,255	8,337	23.0%
South	41,859	17,169	41.0%
Brazil	260,095	61,720	23.7%

Source: Eletrobrás (2002b)

In addition, wind-power can assume a complementary role in the next decades, if promoted by renewable energy policies. With regard to Brazil's wind-power generation potential, a detailed survey was carried out on Brazil's potential wind-power capacity and the findings were published in MME/ELETROBRÁS (2001). According to this survey, Brazil's wind-power could provide 143,470 MW (see Table 3.9). Of this total, 52% of the total potential is located in Northeast Brazil and 21% is located in the Southeast.

TABLE 3.9. ESTIMATED POTENTIAL WIND POWER. ADDITIONAL ISED #35.2

Region	Capacity (GW)	Power Generation (TWh/year)	Capacity Factor (%)
North	12.84	26.45	24
Northeast	75.05	144.29	22
Mid-West	3.08	5.42	20
Southeast	29.74	54.93	21
South	22.76	41.11	21
Brazil	143.47	272.2	22

Source: MME/ELETROBRÁS (2001)

In this case, it is assumed that the potential wind-power capacity covers only areas with average annual wind speeds of over 7.0 m/s, with turbines installed on pylons fifty meters high (state of the art for this technology) and a land occupancy rate of 2 MW/km^2 and an availability factor of 0.98, not including offshore potential (Schaeffer et al., 2002).

So far, only 20.3 MW wind power have been installed in Brazil, accounting for under 1% of the estimated technical potential, with the Prainha (10 MW) and Taíba (5 MW) wind farms in Ceará State being particularly noteworthy, as well as Palmas (2,5 MW) in Paraná State. Therefore, the remaining potential wind-power use in Brazil is almost 100%. Yet, more important than the remaining potential capacity in relative or percentage terms is the information on this potential in absolute terms. Given the low capacity factor of wind power generation, its uncompetitive costs compared with conventional generation and the stochastic nature of the wind, the wind energy technical potential will be feasible in the near future only if promoted by specific policies. However, in some specific locations wind is the less-costly energy option (in some isolated regions). In other specific locations it provides a complementary option to the hydropower generation (wind and hydro seasons are complementary).

Finally, additional indicators covering the Biomass Remaining Technical Potential, expressed by the area used by sugarcane production (see Figure 3.8), are particularly important for Brazil, owing to the significant use of renewable biomass as a substitute for oil products. The most outstanding example of this trend is automotive ethanol, with an entire agricultural and industrial chain established since the introduction of the PROALCOOL (Pro-Alcohol Fuel Program), which was set up to encourage the

production of this energy source[18]. For the entire historical series under consideration here, regardless of whether the sugarcane was grown to produce sugar or ethanol, it is quite clear that only a small fraction of Brazil's arable land is used for this crop[19].

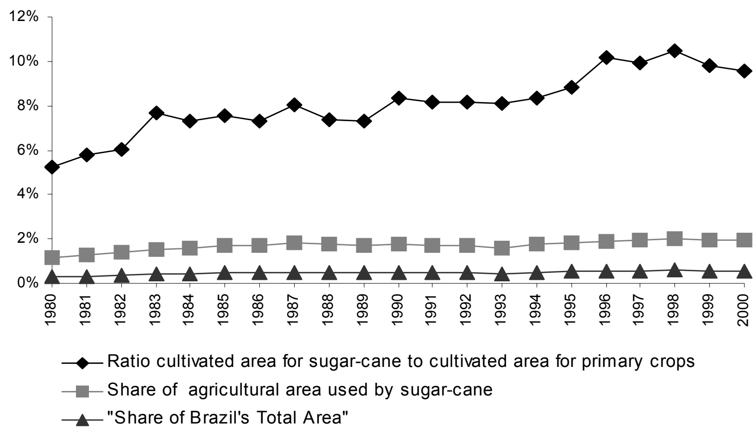

Figure 3.8. Land use for sugar cane in Brazil. Additional ISED #35.3
Source: FAO, 2002.

Brazil's oil reserves include crude and condensate reserves,[20] the latter being classified as liquid fractions of the natural gas obtained through separation processes and stored in the liquid phase under normal temperature and pressure conditions, according to the Brazilian Statistical Yearbook for Oil and Natural Gas ANP (2002b). However, the oil output consists of the production of crude, condensate and shale oil, which is obtained through processing bituminous shale[21] (Schaeffer et al., 2002). Around 65% of the proven oil reserves are located at Bacia de Campos, in Rio de Janeiro State, and almost 75% are located in deep and ultra-deep waters. Indeed, oil exploration and production in ultra-deep waters is a case of success for Brazilian oil engineering. Proven recoverable reserves of oil and gas are presented in Table 3.10 and Figure 3.9.

[18] Productivity gains along this entire chain have been considerable over the past few decades (Moreira et al., 1999). They reflect investments in technology and the absorption of expertise through learning by doing in the production chain, in addition to structured efforts fostering the production and consumption of renewable biomass on large scales.

[19] According to FAO (2002), Brazilian export crops such as soybeans and maize accounted for 21% and 24%, respectively, of the croplands producing primary foods in Brazil, from 1980 through to 2001. For soybeans, significant expansion was noted from 1980 to 2001, up from 17% to 27% of primary croplands.

[20] This indicator is related to the Indicator #37 of the ISED methodology. Data on Brazil's proven oil and natural gas reserves are based mainly on the Brazilian Statistical Yearbook on Oil and Natural Gas *(Anuário Estatístico Brasileiro do Petróleo e do Gás Natural)*, prepared by the National Petroleum Agency (ANP). The data on Brazil's proven coal reserves are taken from the National Energy Balance (BEN). In the case of oil, proven reserves in the Brazilian database are defined for a probability higher than 90% (or are P90 reserves).

[21] Bituminous shale: sedimentary rock, normally clayey, very rich in organic matter (cerogen). When subjected to high temperatures, bituminous shale releases oil, water and gas, leaving behind solid wastes that contain carbon ANP (2002a).

TABLE 3.10. PROVEN RECOVERABLE RESERVES OF OIL AND NATURAL GAS (1980 - 2002) – ISED #36

	1980	1985	1990	1995	2000	2002
				Oil		
Production (1,000 m^3/year)	10,562	31,710	36,590	40,216	71,844	84,434
Reserves (1,000 m^3)	209,540	344,694	715,516	989,385	1,345,746	1,560,158
Oil Res/Prod (years)	19.8	10.9	19.6	24.6	18.7	18.5
				Natural Gas		
Production (1,000 m^3/year)	2,205	5,467	6,279	7,955	13,283	15,568
Reserves (1,000 m^3)	52,544	92,734	172,018	207,964	220,999	236,592
Natural Gas Res/Prod (years)	23.8	17.0	27.4	26.1	16.6	15.2

Source: Based on MME (2001), ANP (2002a) and ANP (2002b).

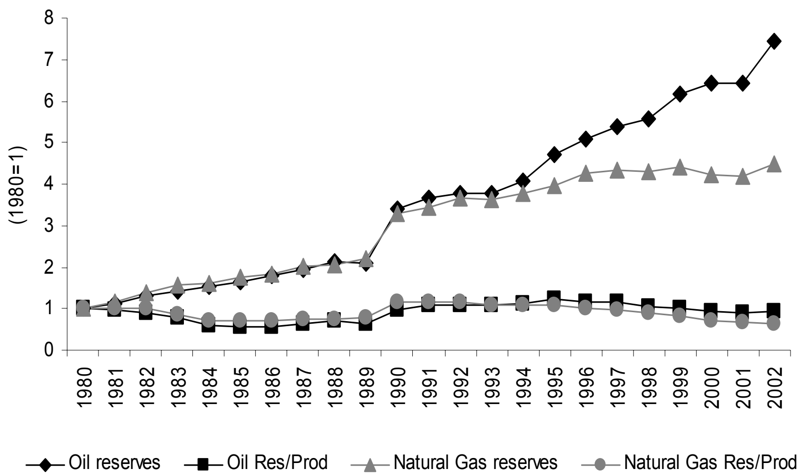

Figure 3.9. Proven recoverable reserves of oil and natural gas (1980 - 2002) – ISED #36
Source: Based on MME (2001), ANP (2002a) and ANP (2002b).

The Brazilian proven reserves of coal equal 32 billion tons and are located in the southern region of the country. Brazilian coal is characterized by its high ash content (average figure of 51%, and hovering between 48 and 54% ROM), low calorific value (hovering between 3,200 and 3,850 kcal/kg), and medium sulphur content (between 0.4 and 2.6%). It is predominantly sub-bituminous and is used mainly for heat generation in the industrial sector and power generation in the transformation sector.

3.2.2. Economic dimension

Economic development has different qualities (or different "development effectiveness"), which lead to different economic development paths. Some paths are more effective than others to create wealth and jobs, to promote well-being and social fairness, as well as to preserve natural resources and to protect the environment for future generations. Actually, quality does matter for economic development as much as for energy.

A common indicator to measure the relationship between energy use and economic development of a country through time is the country's overall energy intensity. The overall energy intensity is the ratio between its total energy use and GDP.

This indicator will be discussed in Section 3.4, which presents the implementation of selected ISED indicators. Yet, it is worthwhile to discuss the evolution of GDP and sector shares in GDP, for manufacturing, agriculture, commercial & public services and transportation.

During the 1980s, the Brazilian economy grew at an average rate of only 1.6% per year and the income per capita growth was negative (-0.4% per year). After the second oil shock in 1979, followed by the financial indebtedness crisis after the 1982 Mexican Moratorium, Brazilian GDP decreased 2.9% in 1983 or 5.2% on a per capita basis. Moreover, after the oil price crises, Brazil had to reduce oil imports. On the demand side, the government introduced some incentives for consumers, mainly in the industrial and transportation sectors, aimed at replacing oil by other domestic sources, such as ethanol automotive fuel. It also reinforced the role of intermediate goods industries in the economy, by promoting electricity-intensive industrial sectors, which justified the undertaking of large-scale nuclear and hydropower projects.

In turn, during the 1990s GDP grew at an average rate of 2.7% per year, but this represented only 1.2% per year on a per capita basis. The most significant institutional reforms took place during this decade. After facing some political and economic instability, which provoked a severe contraction in 1990 (-4.4% growth rate) and stagnation in 1991 (1.0%) and 1992 (-0.5%), the economy bounced back during the 1993 to 1997 period, showing average growth rate of 4.0% p.a. Actually, the economy achieved unprecedented price stabilization after the introduction of an economic plan in 1994. Then, the Asian and Russian Crises, in 1997-98, adversely affected the Brazilian economy (GDP growth rates were 0.1% and 0.8%, in 1998 and 1999, respectively). After this turbulence, the GDP growth rate rose to 4.4% in 2000. Finally, in 2001 and 2002, the Brazilian economy was affected by an electricity supply crisis and growth slowed to 1.5% per year during this period.

Thus, Brazilian economic growth varied considerably during past decades. In general, the economic plans adopted during these decades largely focused on short-term policies, seeking to curb inflation and stabilize the economy.

Finally, it is important to note that the GDP reported is slightly underestimated owing to the share of underground activities in the Brazilian economy.[22] Available data do not allow the correction of this bias.

[22] At the end of the 1990s, this was equivalent to some 10% of Brazil's GDP (Szklo and Cunha, 2004).

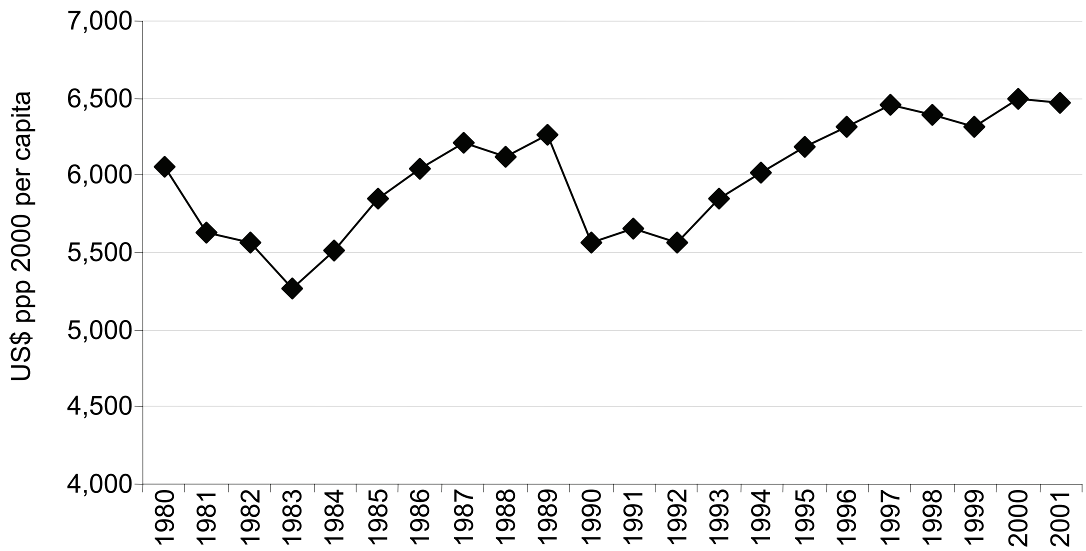

Figure 3.10. GDP per Capita - ISED #2
Source: Based on IBGE (2002), BCB (2002), IPEADATA(2002) and IEA (2000).

3.2.3. Social dimension

A major driving force affecting the country's energy system has been population growth and its concentration. Particularly significant was the growth in urban areas during the second half of the last century. Interestingly enough, eleven Brazilian states' capitals represented more than ¼ of the country's total population at the end of the 1990s (IBGE, 2003a), and in 2000 around 28% of the population was concentrated in cities with more than 500,000 inhabitants (ANEEL, 2002). Per capita GDP (ISED #2) is presented in Figure 3.10.

Given that the country has such marked and severe social disparities, estimates for the ratio between the poorest 20% and the richest 20% are also of interest.

Additionally, it should be stressed that the regional disparities in Brazil are not highlighted when using an average indicator such as those proposed here. For instance, in 1987, 1990, 1993 and 1996, the richest 20% absorbed 81% of the income of the economically active population of the Northeast, but this proportion dropped to 68% in Southeast Brazil over these same years. Consequently, a regional analysis of Brazil may well prove to have significantly different results and should be undertaken to complement this study.

Table 3.11 presents the findings for this indicator.

TABLE 3.11. RATIO OF AVERAGE INCOME PER CAPITA (20% POOREST TO 20% RICHEST) – ISED #19

Year	Ratio	Year	Ratio
1980	n.a.	1989	0.0290
1981	0.0412	1990	0.0319
1982	0.0385	1991	na
1983	0.0386	1992	0.0373
1984	0.0420	1993	0.0346
1985	0.0391	1994	n.a.
1986	0.0440	1995	0.0356
1987	0.0358	1996	0.0335
1988	0.0322	1997	0.0342

Source: Based on PNAD of IBGE (2002).
Notes: PNAD research was not conducted in 1980, 1991 and 1994. Does not include rural areas of the Northern Region. "n.a." means not available.

Therefore, given the income inequalities of the country, the social dimension of sustainable energy development is crucial for Brazil (see Table 3.12). This is even clearer, since regional disparities reinforce income inequalities. For instance, in 1999, although the Brazilian average Gini Index was 0.567, in Paraíba state the figure was 0.644, or around 30% higher than the figure of Santa Catarina State (IBGE, 2002).

TABLE 3.12. MAJOR SOCIAL INDICATORS[23]

Year	Line of Poverty (1)	Gini Index(2)	Income share of 10% richest (%)	Income share of 20% poorest (%)
1992	40.8	0.571	45.81	2.32
1993	41.7	0.600	48.58	2.24
1995	33.9	0.585	47.92	2.29
1996	33.5	0.580	47.59	2.15
1997	33.9	0.580	47.70	2.20
1998	32.8	0.575	47.92	2.25
1999	34.1	0.567	47.45	2.34

Source: IPEADATA 2003, IBGE, 2003a
Notes: (1) This level is defined as the percentage of people earning less than $2.0 per day, exchange rate values. There is no data for 2000. In 2001, the figure was 33.6%. (2) This is the degree of income concentration, considering the income distribution for all workers more than 10 years old; it varies between 0 (perfect equality) and 1 (maximum inequality).

3.2.4. Environmental Dimension

SO_2

Particularly for diesel oil, the Brazilian Government strove steadily to revive the quality specifications for this energy source. Particularly outstanding here is the Diesel Oil Upgrade Program. Table 3.13 shows specifications for sulphur content levels and and recent fuel quality.

For energy sources not based on oil and used in Brazil the following sulphur specifications are assumed (Shaeffer et al., 2001): (1) for Brazilian blended coal used at Candiota, Rio Grande do Sul State, sulfur content at 0.7% (High Heating Value (HHV) at 15 GJ/t) and for the Santa Catarina coal sulfur content at 2.0% (HHV at 19 GJ/t); (2) the most economic imported coal comes from Colombia at 6,000 kcal/kg, with a medium sulfur content level[24], (3) the average sulfur content level in the black-liquor consumed for thermal-power generation by the pulp and paper sector was obtained from Balestieri (1994), at 3.4 percent.

[23] Please note that the indicators presented in the table were not defined under the ISED Project but added by the Brazilian team to express social inequalities and complement the information presented in the ISED Indicator #19.

[24] A sulfur retention figure of 5% was assumed for the fly-ash, which varies from 5% (hard coal) to 30% (brown coal).

TABLE 3.13. SULPHUR CONTENT LEVELS SPECIFICATIONS – RECENT FUEL QUALITY SPECIFICATIONS

Fuel	Date	Sulphur level % w/w	Legislation Administrative Rule
Gasoline A	After 2001	0.12	ANP 309/2001
Gasoline C		0.10	
Gasoline Premium A		0.12	
Gasoline Premium C		0.10	
Regular Gasoline (added 24%±1%)	before de 2001	0.15	
Automotive Diesel A	before 1997	3.00	DNC 32/97
Automotive Diesel B		0.50	
Automotive Diesel C		0.30	
Automotive Diesel B	1998 to 2000	0.50	DNC 32/97
Automotive Diesel C		0.30	
Automotive Diesel D		0.20	
Automotive Diesel (“interior”)	After 2001	0.35	ANP 310/2001
Automotive Diesel (“metropolitan”)		0.20	
Jet-fuel	After 2000	0.30	ANP 137/2000
Fuel Oil B1	After 1999	1.00	ANP 80/1999
Fuel Oil A1		2.50	
Fuel Oil B2		1.00	
Fuel Oil A2		2.50	

Source: Schaeffer et al., 2002.
Note: The sulphur level standards presented here are based on more rigorous quality specifications for the fuels consumed in major cities.

Consequently, based on the information assumed and summarized here, it was possible to estimate the SO_2 emissions from Brazil's energy system. Table 3.14 and Figure 3.11 below summarize these findings.

TABLE 3.14. ANNUAL SO_2 EMISSIONS (KT) – ISED #23

Year	Total Energy Use	Electricity Generation	Transportation
1980	2,133	123	503
1985	2,125	151	530
1990	2,166	177	634
1995	2,824	288	763
2000	2,695	453	207

Sources: ANP Administrative Rules, and MME (2001), ABIQUIM (2002), ABIQUIM (2000), Schaeffer et al (2001) and Balestieri (1994).

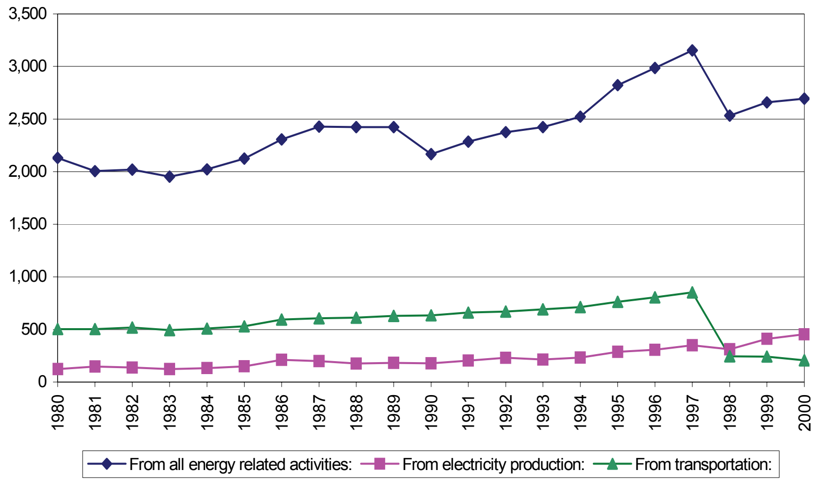

Figure 3.11. Annual SO_2 emissions (kt) – ISED #23
Sources: ANP Administrative Rules, and MME (2001), ABIQUIM (2002), ABIQUIM (2000), Schaeffer et al (2001) and Balestieri (1994).

NO_x

The estimated NO_x emissions are based almost completely on the methodology developed by Schechtman et al. (1998) for calculating the atmospheric emissions from Brazil's energy system. This methodology was applied to the Greenhouse Gases Emissions Inventory, using a bottom-up approach that is available through the website of the Ministry of Science and Technology (MCT, 2002). This also underpinned the development of an accounting model for estimating the emissions of atmospheric pollutants for 1990 through 1994, which is extended to cover an analysis period of 1980 through 2000 during the course of this project.

Nitrogen oxides – NO and NO_2 – are formed from both atmospheric nitrogen during the combustion process as well as the nitrogen found in the fuel. Consequently, the quantity issued depends mainly on the combustion temperature, the surplus air in the combustion chamber, the design of the burner in the furnace, and the fuel composition. These gases react to sunlight in the atmosphere, forming tropospheric ozone that is responsible for photochemical smog; however, it remains in the atmosphere for only a brief period. Using the Schechtman et al. (1998) methodology, almost all the NOx emission factors were obtained through the technology used by the energy-consumption sectors. Nevertheless, for the residential sector, although there was some consumption, there was no emission factor for the kerosene burned for lighting purposes. As fossil fuel use for lighting purposes is minimal and shrinking over time, the difference resulting from the exclusion of these emissions is also minor, and shrinking over time. Consequently, in principle it may be assumed that the total figures for the NO_x emissions by the sectors under analysis do not involve any significant errors owing to the non-inclusion of lighting kerosene. Another exception, for which no NO_x emission factor was found in Schechtman (1998), is the use of fuelwood by the transportation sector. However, once again this minimal use ended in 1991.

Table 3.15 and Figure 3.12 summarize the findings for the NO_x emissions by Brazil's energy system.

TABLE 3.15. ANNUAL NO_X EMISSIONS (KT) – ISED #23

Year	Total Energy Consumption	Electricity Generation	Transportation
1980	1,423	56	788
1985	1,489	67	840
1990	1,587	76	942
1995	1,895	112	1,168
2000	2,376	217	1,357

Source: Based on Schechtman (1998) and MME (2001)

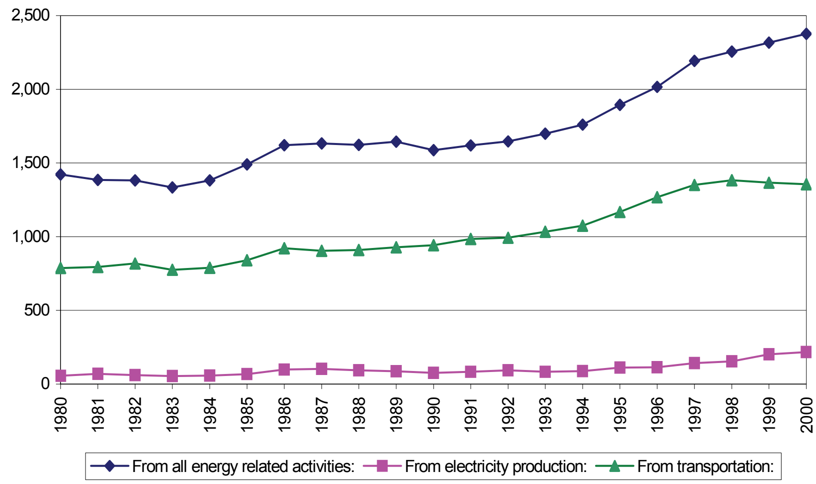

Figure 3.12. Annual NO_x emissions (kt) – ISED #23
Source: Based on Schechtman (1998) and MME (2001)

CO

The annual carbon monoxide emission estimates deriving from energy use in Brazil follow the same methodology used to estimate other atmospheric pollutants. Carbon monoxide results from incomplete combustion of the fuel and is a primary pollutant (formed at the source of the emission). The emission factors were established in Schechtman et al. (1998), according to the energy-consumption technologies in each sector under analysis. However, for the residential sector, although kerosene is consumed for the end-purpose of lighting, no CO emission factors were obtained for this end-use. This does not introduce any sizeable errors into the estimate, because this lighting kerosene use is minimal and shrinking. In fact, a similar line of thought may be followed for the use of fuelwood by the rail transportation sector, as no CO emission factors are available for this consumption, but it is quite low, and ended in 1990.

Table 3.16 and Figure 3.13 below summarize these findings for CO emissions by Brazil's energy system.

TABLE 3.16. ANNUAL CO EMISSIONS (KT) – ISED #23

Year	Total Energy Consumption	Electricity Generation	Transportation
1980	19,403	36	3,919
1985	17,138	59	3,735
1990	15,126	71	4,713
1995	15,181	101	6,323
2000	16,317	147	6,853

Source: Based on MME (2001) and Schechtman et al. (1998)

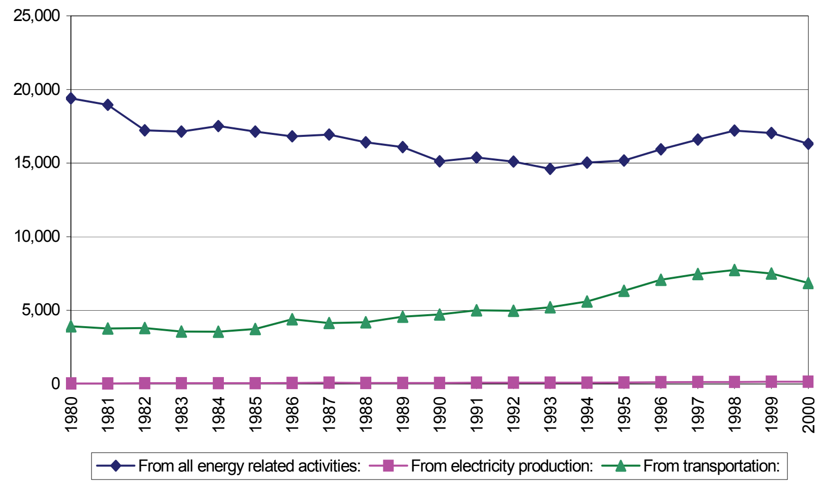

Figure 3.13. Annual CO emissions (kt) – ISED #23
Source: Based on MME (2001) and Schechtman et al. (1998)

GHG emissions

Similar to the previous calculations, estimates of greenhouse gases emissions are based on the methodology and accounting model developed by Schechtman et al. (1998) for the National Greenhouse Gases Emissions Inventory (1990-1994) (MCT, 2002), following a bottom-up approach[25]. However, in this study, it was decided to expand the calculation prepared by Schechtman et al. (1998) covering the Inventory period (1990-1994) to the period under analysis (1980-2000). Furthermore, even for the period covered by the previous inventory, the results of Schechtman et al. (1998) were reviewed, guided by more recent versions of the National Energy Balance (MME, 2001)[26]. This means that the findings obtained here do not necessarily correspond to the findings presented in MCT (2002), with slight deviations owing mainly to the review of the historical figures found in the last version of the National Energy Balance (MME, 2001).

The data provided by ABRACAVE (2002) were of the utmost importance here, covering the percentage of renewable fuelwood used to produce charcoal (see Table 3.17), and the analyses by Schechtman et al. (1996) and Aquino (1999) on fuelwood use in rural parts of Brazil. Consequently, based on these analyses, it was possible to estimate carbon emissions by non-renewable biomass consumed for energy purposes and consequently to total up CO_2 emissions by the Brazilian energy system (deriving from the use of fossil fuels and non-renewable biomass)[27].

[25] These are precisely the findings of this study, available in Brazil's National Greenhouse Gases Communiqué through the website of the Ministry of Science and Technology.

[26] Schechtman et al. (1998) used the National Energy Balance for the 1997 base year (MME, 1998).

[27] According to the analysis, the share held by renewable fuelwood in total fuelwood consumption in Brazil rose from 36% in 1980 to 58% in 2000.

TABLE 3.17. SHARE OF NON-RENEWABLE FIREWOOD CONSUMED FOR CHARCOAL PRODUCTION

Year	%	Year	%
1980	85.9	1990	66.0
1981	81.0	1991	57.7
1982	80.0	1992	61.1
1983	81.8	1993	56.5
1984	83.1	1994	46.0
1985	82.6	1995	48.0
1986	82.7	1996	30.0
1987	80.7	1997	24.6
1988	78.0	1998	32.6
1989	71.2	1999	30.0
		2000	28.4

Source: ABRACAVE(2002)

The emissions of CH_4 (methane) and N_2O (nitrous oxide) were based on conversions of CO_2 equivalent using the 100-year global warming potentials (GWPs) according to the methodology proposed in IPCC (2001), where the methane mass conversion to carbon dioxide equivalent is 23, while for nitrous oxide, this figure reaches 296. Moreover, for these two greenhouse gases, it should be borne in mind that methane emissions depend on both the consumption equipment as well as the fuel. For this hydrocarbon, Schechtman et al. (1998) obtained almost all the emission factors for the consumption technologies used in Brazil, other than (1) LPG emission factors for industrial boilers or boilers installed in tertiary sector enterprises; (2) emission factors for natural gas and city gas consumed in the household sector of Rio de Janeiro and São Paulo (cooking, for instance); (3) the emission factor for lighting kerosene in the household sector; and (4) the emission factors for sugarcane bagasse and other vegetable residues consumed by industrial boilers. Consequently, the findings of this study − based on Schechtman et al. (1998) − are approximate in terms of the average emission factors, and do not include some types of energy use owing to the lack of emission factors. In addition to bringing the total CH_4 emissions estimate down to the lower limit for the total emissions of this pollutant, this stresses the need for a fresh data survey of atmospheric emissions by energy use technologies in Brazil to obtain more complete estimates of the atmospheric pollutants directly related to use technologies, such as CH_4.

Nitrous oxide is one of the greenhouse gases that remain longest in the atmosphere. However, its main source of emission is not burning fuel but rather fugitive emissions from agricultural activities. Consequently, in contrast to what takes place with other atmospheric pollutants analysed here, with this pollutant Schechtman et al. (1998) did not obtain many emission factors for the technologies and equipment used by the energy consumption sectors, demonstrating the need to fine-tune this study through obtaining these emission factors. In objective terms, the N_2O emission factors were obtained in Schechtman et al. (1998) for the following sources: (1) in the industrial sector: fuel oil, diesel oil, kerosene, other secondary oil-based sources, coal, charcoal, petroleum coke and tar; (2) in the commercial and public sectors: fuel oil, diesel oil, natural gas, piped gas, other secondary petroleum and fuelwood sources; (3) in the residential sector: diesel oil, fuel oil, other secondary oil-based sources; (4) in the agricultural sector: fuel oil, diesel oil, fuelwood and charcoal; (5) in the transportation sector: natural gas, diesel oil, gasoline, steam coal, fuel oil, aviation gasoline and aviation kerosene; (6) and finally, for thermal-power generation: diesel oil, fuel oil, tar, petroleum coke and steam coal, consumed to generate high-pressure steam. Consequently, by excluding a considerable portion of the emissions deriving from fossil fuels in these calculations, the N_2O findings presented here are underestimated, calculated almost entirely for use of fossil fuels for Heat Processing purposes, and the transportation sector. In other words, the total findings should be interpreted as the lower limits for N_2O emissions deriving from energy use in Brazil.

Consequently, it is quite clear that there are some significant gaps in the database available for establishing the methane and nitrous oxide emission factors by the energy use technologies available in Brazil. This underscores the need to improve the only broad-ranging database currently available. Notwithstanding, and even though the findings for the emissions of greenhouse gases are underestimated here (which is not the case with the CO_2 emission estimates, for instance), it should be noted that nitrous oxide has a greenhouse effect that is of much significance for emissions deriving from agricultural activities, while only minor

quantities are emitted by the energy sector; and second, there are some (non-major) energy use categories for which no methane emission factors were obtained. Taking these comments into account, Table 3.18 summarizes the findings for the annual greenhouse gases emissions.

TABLE 3.18. ANNUAL GHG EMISSIONS RELATED TO BRAZIL'S ENERGY SYSTEM (MT CO_2 EQ) – ISED #26

Year	CO_2	CH_4 (1)	N_2O (2)	Total GHG
1980	263.6	2.0	0.4	266.0
1985	269.5	2.5	0.3	272.3
1990	273.9	2.6	0.3	276.9
1995	288.4	2.8	0.5	291.7
2000	334.5	2.5	0.6	337.6

Notes: (1) Methane emissions are slightly underestimated owing to the lack of emission factors for some non-major types of energy use. (2) The non-inclusion of a considerable portion of emissions deriving from fossil fuels means that the N_2O findings presented here are underestimated, calculated almost completely for fossil fuel use under the Process Heat heading and for the transportation sector.
Source: Based on MME (2001), Schechtman et al. (1998), ABRACAVE (2002), Aquino (1999), Schechtman et al. (1996), IPCC (2001).

3.3. Review of the Energy Statistical Data Capability

3.3.1. Brazil's Energy Database Review[28]

There are two key databases for the preparation of sustainable energy development indicators in Brazil:

One is run by the Brazilian Institute of Geography and Statistics (IBGE - Instituto Brasileiro de Geografia e Estatística) / www.ibge.gov.br, which is the main provider of data and information on Brazil, with the following functions:

- Collection and analysis of statistical information;
- Coordination and consolidation of statistical information;
- Production and analysis of geographical information;
- Structuring and implementing an environmental information system;
- Documentation and dissemination of information;
- Coordination of national statistical and geographical systems.

Based on these activities, the IBGE produces and makes available to the public:

- Social and Demographic Statistics: These are based largely on data collected from households. Outstanding among them are: the Demographic Census, which is undertaken every ten years and forms the core of Brazil's social and demographic statistics; the Headcount, which is carried out between demographic censuses to fine-tune the annual population estimates; the National Household Sampling Survey (PNAD - Pesquisa Nacional por Amostra de Domicílios) which is an annual survey of information on housing, income and the labor-force, as well as some demographic characteristics obtained through sampling Brazilian households; and the Family Budget Survey (POF - Pesquisa de Orçamentos Familiares) which is carried out every five years, offering more detailed information on the structure of family incomes and expenditures. Finally, surveys such as the Medical and Sanitary Assistance Survey (Pesquisa de Assistência Médico-Sanitária) and the National Basic Sanitation Survey (Pesquisa Nacional de Saneamento Básico) provide information on the basic infrastructure services rendered to the Brazilian residential sector.

[28] This section is based on the first-year progress report of the ISED project (Schaeffer et al., 2002).

- Agricultural Statistics: These are based on the agricultural census that surveys farming and ranching establishments, providing information on the land-owning arrangements (land ownership and use); the labour-force occupancy profile; and the technological levels absorbed by the production process. The latest version of this census covers 1995-1996. For annual information on this sector, the Municipal Agricultural Survey (Pesquisa Agrícola Municipal) is particularly helpful.
- Economic Statistics: Information on major economic sectors based on sampling surveys for establishments in each sector: Annual Trade Survey (Pesquisa Anual do Comércio); Annual Industrial Survey (Pesquisa Industrial Anual); Annual Construction Industry Survey (Pesquisa Anual da Indústria de Construção); and Annual Services Survey (Pesquisa Anual de Serviços).
- Price Indices: Produced systematically through an ongoing process, the Consumer Price Indices allow monthly monitoring of the prices of the main products and services consumed by the population.
- National Accounts System: This database offers an overview of the Brazilian economy as a whole, following the latest recommendations issued by the United Nations in its System of National Accounts (SNA) 1993, including the calculation of the Gross Domestic Product and the Input-Output Mix.
- Geographical Information, Geographical Mapping and Charting the Natural Resources in the Environment: This information is constantly updated, available through the IBGE website.

The second key database is the National Energy Balance. This is the only source of energy data in Brazil covering all energy supply, transformation and consumption sectors. In itself, this justifies the logic of assigning high importance to the National Energy Balance (BEN - Balanço Energético Nacional), turning to other specific sources of energy-based data only when this National Energy Balance does not provide reliable information. Elaborated annually by the Ministry of Mines and Energy (MME) since 1974, it has used the same methodology since 1981, presenting the energy flows for primary and secondary energy sources from production through to final consumption in the main economic sectors. Each year, the data for the previous year are included, with the data for the two years prior to the base year of the National Energy Balance being reviewed. In principle no alterations to the data for earlier years takes place. This Balance covers many different economic sectors, such as: the energy sector itself, residential, commercial, public, agricultural, transportation and industry. In turn, the transportation sector is broken down into: road, rail, air and water, while the industrial sector is broken down into: cement, pig-iron and steel, ferroalloys, mining and pelletizing, non-ferrous metals, chemicals, food and beverages, textiles, pulp and paper, ceramics and other industries. Finally, this publication is divided into nine chapters:

- Summary of fifteen-year historical series. This offers a synopsis of the energy data for the base year and the consolidated energy, production, consumption and foreign dependence figures. It also offers a breakdown of sectoral consumption by different groups of energy feedstock.
- Energy supply and demand by source for the fifteen-year series retrospective to the base year. For each primary and secondary energy source, it presents the production, import and export accounts, in addition to stock variations, losses, adjustments and total consumption, the latter broken down by economic sector.
- Energy use by sector for the fifteen-year series retrospective to the base year, presenting the final energy use for each economic sector, broken down by each primary and/or secondary source.
- Foreign trade in energy for the fifteen-year series retrospective to the base year, presenting the energy imports, exports and foreign dependency figures.
- Energy transformation units balance for the fifteen-year series retrospective to the base year, presenting the balances for the energy transformation units and showing their energy input and output with their respective processing losses.
- Energy resources and reserves since 1972. This presents the resources and reserves for the primary energy sources and their respective calculation methodologies.
- Energy and socio-economic factors. This presents the energy, economic and population indicators – specific consumption, energy/GDP ratios, outlays on foreign exchange earnings, energy source

prices, etc. In this case, some information made available through the Balance is similar to those provided by the IBGE. However, as the National Energy Balance does not always use the same methodology as IBGE for sectoral breakdowns, and as the constant currency data in the Balance does not indicate the deflation methodology used, it was considered that sources of information on monetary data other than the National Energy Balance would be more appropriate for this study.

- State energy information for the fifteen-year series retrospective to the base year, presenting partial information on State and regional energy balances and energy/population ratios.
- An appendix presenting the following information: Brazil's installed power generation and refining capacities; the concept behind the Balance methodology; the data source institutions for the Balance; and the Consolidated Energy Balances from 1974 onwards[29].

These two databases are used in this study on a preferential basis, as they are the broadest-ranging and consequently offer the largest amount of compatible data in terms of collection periods and activity classification. In other words, these two databases are used in this study unless other sources of information can bridge certain gaps, or if the information in either of these two databases seems less reliable than data from some other source for a specific reason [30]. It should also be recalled that both the National Energy Balance and the publications issued by the IBGE underpin much of the data collected from sectoral sources such as industrial producer associations, business associations for tertiary sector segments, town councils, energy enterprises, power regulators, etc. As these sectoral data sources frequently do not work with the same data classification as the two broader-ranging sources that are preferably used here, their selection for subsequent aggregation at the national scale should be handled with care[31].

Ancillary data sources for the type of study undertaken here are:

- IPEADATA: This is a database available over the Internet from www.ipeadata.gov.br, organized by the Institute for Applied Economic Research (IPEA – Instituto de Pesquisa Econômica Aplicada) that contains information on 1,900 annual series and 2,600 monthly series on the balance of payments, foreign trade, consumption and sales, national accounts, international economics, employment, public finance, social indicators, interest rates, currency and credit, population, prices, production, wages and income[32].
- Banco Central do Brasil (BCB): www.bacen.gov.br
- National Petroleum Agency (ANP): This Regulator provides information and documents for download, mainly through its website (www.anp.gov.br) in addition to its Statistical Yearbook.
- Petrobras: The Brazilian oil enterprise provides information, mainly through its website (www.petrobras.com.br).
- National Electricity Agency (ANEEL): This Regulator makes information available through its website (www.aneel.gov.br), with a database that is constantly updated for installed power generation capacity, electricity prices and power sector regulations. It also has historical series providing information on the power sector for periods after 1995.
- Eletrobrás: The website of the holding company of Brazil's power sector (www.eletrobras.gov.br) provides information on the power sector and also offers documents for download that range from technical analyses of market development and the power generation segment to information on rates and regulations (SIESE).

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[29] These are the annual matrices that consolidate all energy flows from the various primary and secondary sources.

[30] This is not the case with the IBGE (2002) data in general, although it does apply to some information in the National Energy Balance (MME, 2001).

[31] Although the National Energy Balance (MME, 2001) may be taken as summarizing Brazil's energy data, other sources of primary and secondary energy data are available, using different methodologies to obtain and process this information. For instance, industrial associations and power consumer groups produce these data, which are not always classified in the same way as in the National Energy Balance. Moreover, with the deregulation of Brazil's energy sector, more knowledge is needed about the databases set up by the private sector in terms of their regularity, availability and trustworthiness.

[32] Much of this information comes from primary sources, particularly the IBGE.

- Ministry of Science and Technology: This Ministry provides documents for download at its website (www.mct.gov.br) related specifically to the Brazilian National Inventory on Greenhouse Gas Emissions.
- Ministry of Mines and Energy: The website of this Ministry (www.mme.gov.br) offers the latest version of the National Energy Balance for download, in addition to documents linked to the websites of Government programs in Brazil's energy sector such as the Light in the Countryside Program (Programa Luz no Campo) and the State and Municipal Energy Development Program (Programa de Desenvolvimento Energético de Estados e Municípios).
- ANFAVEA (www.anfavea.com.br), ANTP (www.antp.org.br) and GEIPOT (www.geipot.gov.br): these three databases cover the transportation sector:
- The first is provided by the National Association of Automotive Vehicle Manufacturers (ANFAVEA – Associação Nacional dos Fabricantes de Veículos Automotores), which is an entity bringing together the manufacturers of automotive vehicles and agricultural machinery. Its website provides information on the automobile industry, the domestic market, and exports by Brazil.
- The second is the website of the National Public Transportation Association (ANTP – Associação Nacional de Transportes Públicos), whose website provides information drawn from statistical yearbooks dating back to the 1990s on passenger-kilometers, distances traveled, and urban bus fleets in major Brazilian cities.
- The third is the Brazilian Transportation Planning Enterprise (GEIPOT – Empresa Brasileira de Planejamento de Transportes) whose website provides information broken down by mode of transportation through the Transportation Statistical Yearbook.
- ABRACAVE (www.abracave.com.br): The website of the Brazilian Renewable Forests Association (Associação Brasileira de Florestas Renováveis) provides information on renewable biomass, particularly the production and consumption of charcoal made from renewable sources (planted forests).
- INPE (www.grid.inpe.br): The website of the National Space Research Institute (Instituto Nacional de Pesquisas Espaciais) provides information on deforestation, bio-diversity and satellite images of Brazil.
- EMBRAPA (www.embrapa.br): The Brazilian Agricultural Research Enterprise (Empresa Brasileira de Pesquisa Agropecuária) provides agricultural information through its website.
- The Brazilian Central Bank and Getúlio Vargas Foundation (FGV): these two databases provide financial and economic information through their websites (www.bcb.gov.br, and www.fgv.br).
- Energy Consumer Enterprise Association Yearbooks: Particularly ABIQUIM (Chemical Industry), ABAL (Aluminum), IBS (Steel), ABRASCE (Malls), ABRACE (Major Industrial Power Consumers).
- International Databases, particularly the United Nations Food and Agriculture Organization – FAO (apps.fao.org), the Energy Information Administration – EIA (www.eia.doe.gov), the International Energy Agency – IEA (www.iea.org) and the World Bank (www.worldbank.org).

Another important aspect concerning the database sources used in this study is related to the economic information found in the National Energy Balance, as well as the IBGE Statistical Yearbook, providing aggregate energy data. In this case, this study considered it more appropriate to tap the IBGE for economic information and the National Energy Balance for energy data, regardless of any possible intersections between these two main databases.

3.3.2. Building Database Capacity

As a summary, it is possible to say that Brazil's energy and economic data are reasonably adequate but should be improved. Firstly, as clearly identified in the first-year ISED report, it is particularly noteworthy that the Ministry of Mines and Energy − which is responsible for the National Energy Balance − implements a joint project with the IBGE aiming to harmonize this Balance with Brazil's National Accounts System. This also means that the IBGE should break down relevant energy products and services in the National Account System. For instance, in this database, Electricity, Water & Sewage, Gas Production & Distribution are grouped under Public Utilities Industrial Services (SIUP – Serviços Industriais de Utilidade Pública), while Fuelwood & Charcoal and Other Agricultural Products are grouped under Other Agricultural Products. At least, in the short-term, the IBGE should regularly disclose the weighting factors that allow these products and activities to be disaggregated.

Secondly, some coordination and better classification should be done to make different data sources compatible, especially the National Energy Balance and Yearbooks of Industrial Associations and Regulatory Agency. Particularly important is the fact that these data sources do not provide the methodology of their data compilation or acquisition, the validity of the database, and some important characteristics such as period of analysis and collection, and economic activity classification. Furthermore, the distinction of independent power producers and self-generators that eventually export surplus power, and the differences between self-consumption and energy transformation or commercialization are not clear in all sources, undermining the direct use of them.

Thirdly, some important information is missing in the Brazilian database. The information regarding power tariffs (with and without taxes) is not clear and lacks sufficient data. Information concerning investments is dispersed and not reliable. The transportation sector database lacks important information. Most of the official data on the transportation sector in Brazil is provided by the Brazilian Office for Transportation Planning – GEIPOT (a body of the Ministry of Transportation) in the Statistical Yearbook of Transportation [15][33]. These include data addressing the distance travelled by passengers, freight transport activity and fleets. Actually, like the Brazilian Ministry of Energy and Mines, GEIPOT itself does not perform primary data surveys to prepare its Statistical Yearbook. Instead, GEIPOT consolidates surveys performed by other institutions (both governmental and private). However, total passenger activity figures and, as a consequence, the indicators derived were underestimated in our study, since passenger activity by aquatic mode of transportation is not included in most of the years of GEIPOT statistics. Also, GEIPOT statistics do not included passenger activity by rail mode of transportation for the year 2000 either (not reported to GEIPOT yet). Additional efforts should be made in the future to correct those biases[34].

Furthermore, GEIPOT statistics for urban public transport contains only data on urban trains and trolleys, missing the lion's share of the urban public transport. To avoid misinterpretation, this indicator was not reported in this study. However, on behalf of sound transport planning and policies, it would be very important for Brazil to improve the basic information data on transportation, overcoming the weaknesses and limitations of the current approach (which is technically possible, but dependent on political and financial resource allocation priorities).

[33] It is important to point out that, as part of the Brazilian State reform, GEIPOT will be eliminated (Decree # 4.135, Feb/20/2002) and its duties and responsibilities will be assumed by the new regulatory agencies for the transportation sector. However, it is not clear so far whether or not the Statistical Yearbook of Transportation will continue to be published (it could be published by the Ministry of Transportation; just as the Brazilian National Energy Balance which is published by the Ministry of Energy and Mines).

[34] Part of the problem seems to be related to the recent changes in the transport regulation in Brazil. On one hand, some state-owned transportation companies were privatized and stopped providing basic information on their activities (which might be temporary). On the other hand, changes associated with the state reform in Brazil (progressive replacement of GEIPOT by regulatory agencies) seemed to affect the ability of GEIPOT in requesting and organizing the primary data on transportation. It is expected that when this transitional period is over the relevant government bodies will recover their capacity for providing basic information on transportation.

In addition, the fleet database, which constitutes one of the major items of information for the Brazilian energy system, is not reliable since it can be based on different sources with very distinct information.[35] The use of hydrated ethanol depends on the ethanol-fuelled fleet. Among other reasons, this explains why the description of the country's light vehicles fleet is so important. The GEIPOT Statistical Yearbook of Transportation can be considered as the official source for fleet data.[36] However, according to the technical staff of Petrobras (the Brazilian National Oil Company), such a methodology overestimates the fleet by adopting a very conservative depreciation rate and by double-counting vehicles by waiting three years to deduct interstate transfers. After 1984, the latter problem seems to have been solved by checking double counting based on license plate and chassis numbers. Even so, according to Mattos et al (1996), GEIPOT fleet data are still overestimated. According to the alternative methodology to estimate the fleet proposed by Mattos et al (1996): first, the annual vehicles sales informed by ANFAVEA (time series: 1957-2001) are accumulated; then, based on probabilistic reliability theory, the vehicle depreciation curve of Brazil is derived; and, finally, the vehicles assumed to be depreciated out of total vehicle sales stock are deducted.

Fourthly, Brazil' s database lacks reliable information on renewable biomass. This study was based on academic works and the project team's experience regarding this issue, but reliable information on fuelwood gathering and planted forests is still a major issue. Moreover, the fuelwood use estimates in Brazil are also subject to several uncertainties.

Finally, the industrial energy use database is not as comprehensive as it should be. It has no reliable and recent energy data on equipment or useful energy levels that would help in specifying energy efficiency potentials and in assessing pollutant emissions. An equipment inventory would be very helpful in this sense. It does not provide the quality of energy used by the industry. Since this sector is responsible for the majority of the heat demand in Brazil, it will be very useful to have information concerning the quality of this heat. This kind of information is the basis for an integrated energy plan for the Brazilian industrial sector.

As a last comment, it should be stressed that the new context for Brazil's energy sector requires a study of the mechanisms for obtaining information from private companies. Actually, the transition from a model based on State-run enterprises to private utilities has endowed these data with strategic characteristics. Initially, the flawed definition of "strategic information" and the failure to establish protection mechanisms for this "strategic information" may well hobble its regulation and hamper the crucial task of planning for Brazil's energy sector.

Regarding the ISED database, the Brazilian team identified these major issues: (1) the ISED set does not consider the use of ethanol as an automotive fuel, besides its importance to Brazil's energy mix. An important indicator that could be considered is the ethanol final price, since this automotive fuel might compete with gasoline, provided that new cars fuelled by ethanol are produced in Brazil. In this sense, the fleet database could be used as a first proxy of the transportation sector when more detailed data are not available; (2) the ISED set does not include an indicator for the use of charcoal in the reduction process of Brazil's iron and steel industry; (3) the ISED set is not totally appropriate for determining the potential use of alternative sources in countries like Brazil, especially biomass-based power generation and wind power generation; and (4) the ISED set is not very useful for identifying regional and even social disparities. These are major issues for the Brazilian case.

Therefore, following the methodology developed under the ISED project, this study adopted a set of additional indicators to better reflect Brazil's energy sector specificities – for instance, the importance of hydroelectricity for power generation, the large use of ethanol as automotive fuel, the relevant remaining potential for using sugar-cane bagasse fired-cogeneration and wind-power, and the significant use of LPG in the household sector. These additional indicators were used for analysing the Brazilian energy system in Section 3.2, and for assessing energy policies according to the main priority areas defined in Section 3.4.

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[35] In the first-year report, we added the indicator "Fleet (light vehicles - road) (millions)" as an additional indicator to emphasize the importance of the Brazilian ethanol fuel program in the 1970-1980s.

[36] Such data are obtained by deducting vehicles assumed to be depreciated out of the total road motor vehicles registered in each State Transit Departments of Brazil (DETRANs), which are consolidated by a National Transit Department (DENATRAN). The criterion used to estimate the vehicle depreciation is the simultaneous occurrence of two events: no records of annual payment of the vehicle ownership tax (IPVA) and of fines for three subsequent years.

However, new indicators could be developed especially for assessing regional features of the Brazilian energy system.

3.4. Identification of Major Priority Areas

To fulfil the requirements of the ISED project, this report has identified two main priority areas of Sustainable Energy Development for Brazil, which are summarized below.

3.4.1. Diversifying the energy mix, while promoting sustainable development

Regarding the supply side, the identified priority area is to diversify the energy mix, while promoting sustainable development, mainly by increasing the use of renewable energy resources.

Diversifying energy supply would reduce the risk of power shortages or price shocks in the future. It also implies a more suitable utilization of Brazilian energy resources, to emphasise the expansion based on indigenous sources and domestically-developed technologies. Within this context, Brazil has plentiful renewable energy resources including hydro, wind, solar, and bioenergy resources. Expanding renewable energy utilization could help to diversify energy supplies, stimulate new industries, create jobs, and contribute to economic and social development of poorer rural regions of Brazil.

Another major consequence of such renewable-based energy supply expansion policy is the potential reduction of energy imports. Energy imports are mainly in the form of petroleum and petroleum by-products, but electricity and natural gas imports are up as well.

Finally, to some extent, these new energy supplies are also making feasible the reduction of some adverse environmental impacts, as is the case of existing ethanol production compared with high-impact oil drilling and refining. The same comparison can be done in the case of small-scale hydro power plants and bagasse cogeneration units, compared with high-environmental-impact large hydropower dams.

3.4.2. Promoting energy efficiency, whilst reducing regional energy use disparities and improving energy affordability

Regarding the demand side, the major priority area includes the promotion of energy efficiency, whilst reducing regional energy use disparities and improving energy affordability.

Within this context, it is of utmost importance to emphasize that enhancing the efficiency of energy use in Brazil is extremely cost-effective. For instance, a recent survey of electricity conservation measures implemented by distribution utilities shows an average of some US$ 20-30 per MWh saved by the project (Schaeffer et al., 2001). In contrast, during the first six months of 2002 the average residential tariff in Brazil was US$ 80/MWh and the average industrial tariff was US$ 36/MWh (ANEEL, 2002). Furthermore, the current marginal cost of supplying electricity from different power generation technologies varies from US$ 20/MWh for some hydroelectric power plants to US$ 40/MWh for natural gas-fired thermal power plants, which are the preferred choices for expanding the Brazilian power sector. This shows that saving electricity is cheaper than supplying it, with a wide range of benefits that include fewer possibilities of power shortages, a keener competitive edge for Brazilian industries and products on global markets, and the fact that conserving electricity has far more favourable environmental and social impacts than supplying it.

In addition, as pointed out by Szklo and Geller (2005), Brazil has had some success with increasing the efficiency of energy use. But many industries, businesses, and households still waste energy because of inefficient industrial processes, out-dated equipment, vehicles, and buildings. For example, motors used in Brazil are inefficient by international standards as well as oversized and poorly operated in many cases (Geller et al. 1998); in the residential sector, using more efficient appliances could cut electricity use by nearly 30 percent (Almeida et al., 2001); and heat integration in the chemical sector could achieve 5 to 15 % of fuel savings (Tolmasquim et al., 2003).

Increasing the efficiency of energy use would save consumers income, reduce the cost of the Brazilian enterprises and reduce the risk of new energy shortages. However, as important as these, a lower energy

intensive economy would release the pressure on the government's budget related to infrastructure. This particular feature is key to implementing large-scale effective social policies, which compete with other items of the Government's budget for limited funds.[37]

Finally, by promoting energy efficiency, Brazil should also be able to improve the standard of living of the poorest portion of the country's population, which has far from acceptable minimal energy use levels. Currently, about 5 percent of all households in Brazil do not have access to electricity service. Some low-income households earning less than $150 per month still rely on wood as a major energy source. Increasing access to and use of modern energy sources by all households would reduce social and regional inequality, and create jobs and job opportunities in underdeveloped rural areas.

3.5. Implementation of ISED Framework

3.5.1. Initial Comments

Following the methodology developed under the ISED Project, this study adopted a set of indicators that are related to its main concerns. In this set, a few additional indicators were developed to match more adequately Brazil's energy sector specificities – for instance, the importance of hydroelectricity for power generation, the large use of ethanol as an automotive fuel[38], the relevant remaining potential for using sugar-cane bagasse fired-cogeneration and wind-power, and the huge use of LPG in the household sector.

Table 3.19 and Figure 3.14 present the total set of indicators adopted. Given the purpose of this study, a number of additional comments regarding the importance of additional indicators are warranted, as follows:

The ISED set does not explicitly address the use of ethanol as an automotive fuel. One important indicator is ethanol's final price, since this automotive fuel might compete with gasoline. In this sense, the fleet database might be used as a first proxy of the transportation sector. The ISED set does not cover the specific use of charcoal in the reduction process of the iron and steel industry. The ISED is very conservative about the potential use of alternative sources in countries like Brazil, especially biomass-based power generation and wind power generation.

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[37] Investments in the energy sector averaged about 9 percent of total capital investments in Brazil during the 1990s. Much of the investment in energy supply is now provided by the private sector or by profitable state-owned (or partially state-owned) companies such as the national petroleum company, PETROBRAS. However, a significant portion of the investment comes from the public sector.

[38] Ethanol is used mainly as an additive for gasoline (26% in volume), i.e. anhydrous ethanol at 99.6 GL and 0.4% water, mainly for local environmental reasons. The other alternative is the use of hydrated ethanol (95.5 GL) in engines solely fuelled by ethanol or in flex-fuel cars.

TABLE 3.19. INDICATORS SET

Dimension	ISED set	Additional Indicators(3)
Economic		
Indirect Driving Force	1. Population (1.1, 1.2.)	3.1.4. End-use energy price for gasohol
	2. GDP per capita (2.1, 2.2)	3.1.5. End-use energy price for ethanol
	3. End-use energy prices (3.1 to 3.3)(1)	3.3.8. End-use energy price for city gas
	4. Shares of sectors in GDP value added (4.1 to 4.4)	11.1.8. Final Energy Mix. Combustible Non-renewable biomass (non-renewable firewood and charcoal)
	5. Distance travelled per capita by passengers (5.1 to 5.3)	11.3.9. TPES: Combustible Non-renewable biomass (non-renewable firewood and charcoal)
	6. Freight transport activity (6.1 to 6.5)	11.4. Anhydrous Ethanol Added to Gasoline.
	8. Manufacturing value added by selected energy intensive industries (8.1 to 8.6)	11.5. Fleet of cars (ethanol, gasoline, diesel)
	9. Energy intensities (9.1, 9.2.) (2)	
	10. Final energy intensity of production (10.1 to 10.7)	
	11. Energy mix (11.1 to 11.3)	
	12. Energy supply efficiency (12.1 to 12.6)	
Direct Driving Force	14. Energy per unit of GDP (14.1 to 14.3)	
	15. Expenditures on energy use (15.1, 15.3, 15.4)	
State	16. Energy consumption per capita (16.1 to 16.4)	
	17. Indigenous energy production (17.1 to 17. 2)	
	18. Energy net import dependency (18.1 18.6)	
Social		
Indirect Driving Force	19. Ratio of average disposable income/private consumption per capita to that of 20% poorest of population (19)	
	20. Ratio of daily disposable income of poorest 20% household to energy prices (20.1 to 20.3))	
Direct Driving Force	21. Fraction of disposable income/private consumption per capita spent on fuel and electricity (21.1 to 21.2)	
State	22. Fraction of households (22.1 to 22.2)	

Environmental		
Indirect Driving Force	--------------------------------------	
Direct Driving Force	23. Quantities of air pollution emissions (23. 1 to 23.3). 26. Quantities of GHG emission (26.1 to 26.5). 35. Fraction of technically exploitable capability of hydropower currently not in use (35) 36. Proven recoverable fossil fuel reserves (36.1 to 36.3)	35.2 Fraction of technically exploitable capability of windpower currently not in use 35.3. Share of agricultural area currently used by CRW 35.4 Share of potential agricultural area used by CRW 35.5 Technical Potential for Hydropower 35.6 Technical Potential for Windpower
State	37. Lifetime of proven recoverable fossil fuel reserves (37.1 to 37.3) 40. Intensity of use of forest resources as fuelwood. (40) 41. Rate of deforestation (41)	

Notes: (1) Indicators 3.1.1, 3.1.2, 3.2.2., 3.3.2, 3.3.4, and 3.3.5 for the end-use energy prices were not considered given Brazilian specificities – for instance, the irrelevant demand for space heating in the household sector. (2) The indicator 9.1.5 was not considered since Brazil’s yearly demand for space heating is almost zero. (3) These additional indicators are related to Brazil’s energy system specificities not comprised in the ISED set.

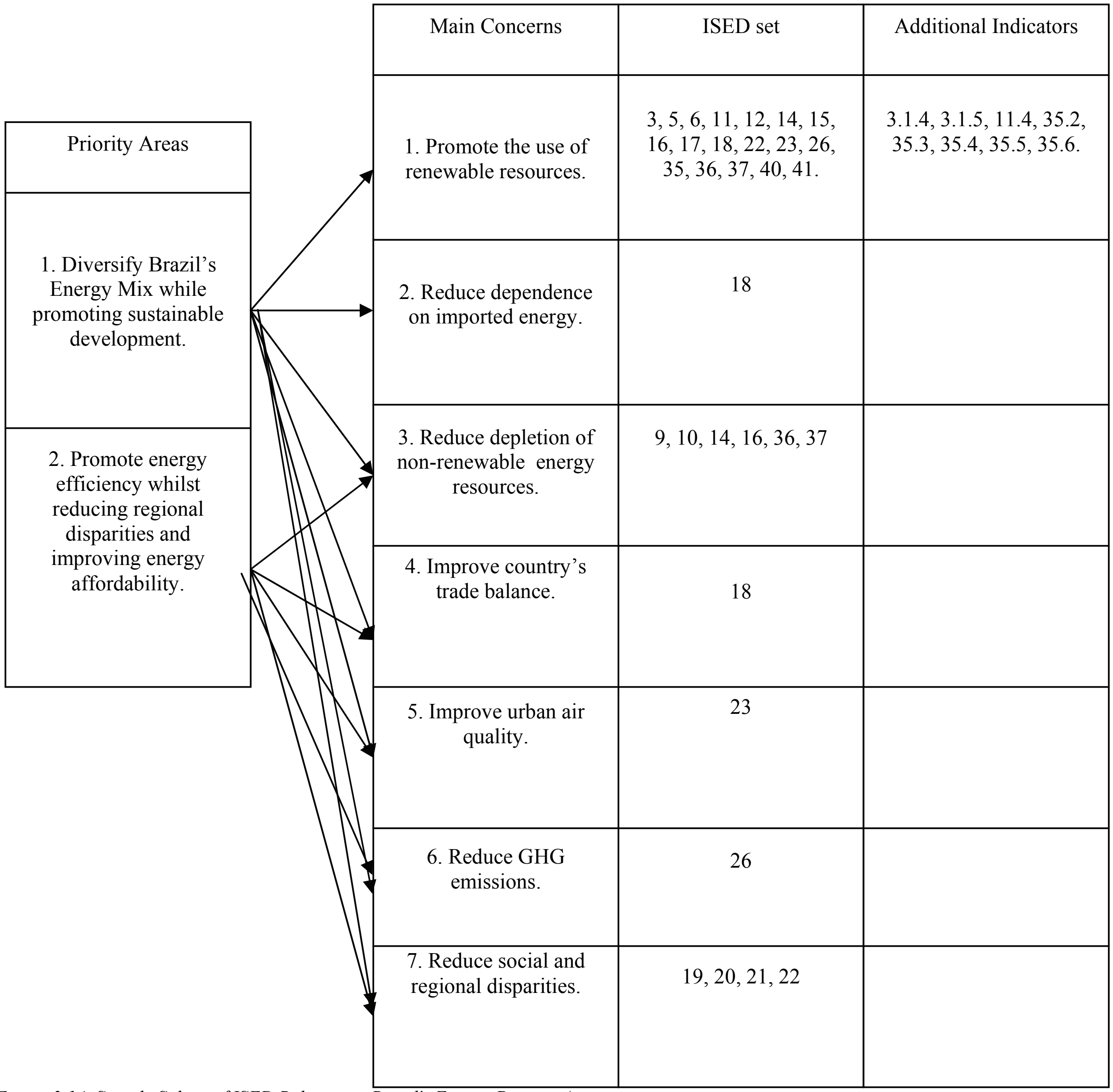

Figure 3.14. Sample Subset of ISED Relevant to Brazil's Energy Priority Areas

The data compilation related to the selected ISED indicators was presented by the first-year report of the ISED Project.

3.5.2. Implementation of the ISED Indicators[39]

The Section 3.4 identified two main priority areas: first, in Brazil's energy supply sector, to diversify the energy mix whilst promoting sustainable development, mainly by encouraging the use of renewable energy resources; second, in Brazil's energy demand sector, to promote energy efficiency while reducing regional disparities and improving energy affordability. These two main priority areas address the social dimension (energy disparities, accessibility and affordability), the economic dimension (energy pricing, end-use energy intensities, and external dependence), and the environmental dimension (air pollution and energy resources depletion) of Brazil's energy sector.

[39] This section is based on the 2004 draft chapter 2 of the study "Brazil: a country profile on sustainable energy development," written by Szklo and Cunha (2004).

This subsection conducts a preliminary review of the status of the priority areas defined above, following the ISED and the additional indicators proposed by the Brazilian team, whose data compilation was completed in the Section 3.3.

3.5.2.1. Economic and Social Dimensions

Urbanization and Energy Accessibility

The first ISED indicator refers to Population Data as an indirect driving force for the economic dimension of sustainable energy development. Indeed, although important in absolute terms, population growth is a driving force that is increasingly less significant for the expansion of energy use in Brazil, compared to other driving forces such as alterations in the consumption standards of the population, the income distribution and access to consumer goods. These other driving forces are more closely related to the rising concentration of the Brazilian population in urban areas, up from 67.6% in 1980 to 81.2% in 2000 (see Figure 3.4 in Section 3.1).

The urbanization process affected the number of households with access to infrastructure networks (electricity, water and sewage) in Brazil, the ownership of household appliances (even among the lower-income segments of the population), and above all the average behaviour standards for the Brazilian population, whose values shifted over the course of the past century from a predominantly agrarian field of influence to one that is almost completely urban. The use and even the perception of physical space, time and natural resources has thus changed dramatically.

Less than 5% of total households still lack electricity (see Figure 3.15), but some 25% of rural households in Brazil do not have access to electric lighting, and this proportion is even higher in the North and Northeast (Tolmasquim, 2003). Consequently, lack of access to the electric power grid (one indicator for sustainable energy development in Brazil) is primarily a regional problem. It is indirectly linked to the concentration of the population in rural areas and to income distribution patterns among the various regions of the country – around 90% of the households lacking electricity in Brazil have an annual income of less than 550 US$ ppp 2000 (Tolmasquim, 2003). Major cities tend to cluster investments in infrastructure, and larger scales offer network economies for public services.

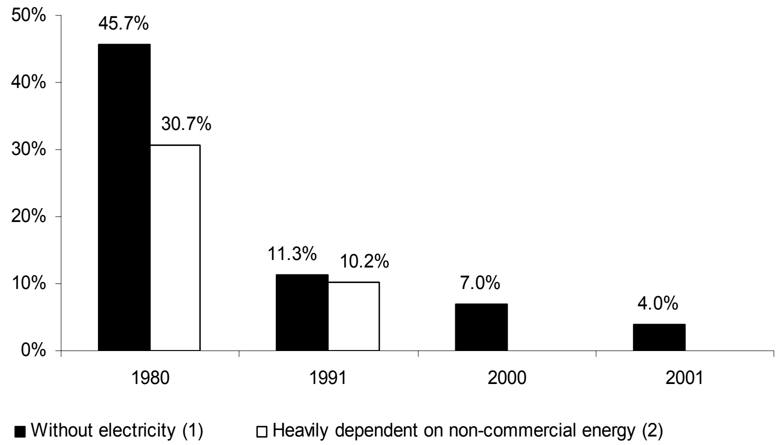

Figure 3.15. Energy Accessibility Indicators – ISED #22
Source: IPEADATA 2003.
Notes: (1) Families without electricity meter, (2) Families that own fuelwood oven. Data after 1991 are not available. However, recent estimates made by Szklo et al (2004) show that the share of households depending on fuelwood for dedicated or non-dedicated consumption (dual-fuel stoves for LPG and fuelwood) was still 10% in 2000. These lesser-income classes' households are mostly located in rural areas, and their fuelwood consumption is explained not only by lack of accessibility to modern fuels (e.g., LPG and natural gas), but also by affordability issues (which is the case of consumption in dual fuel stoves).[40]

Therefore, although per capita power consumption varies considerably by income level among the population, access to electricity among the lower-income layers is almost universal in urban areas in Brazil. Constraints on higher per capita power consumption are related to available income, not the lack of physical access to the power grid. In this case, access to the power grid is a problem more specific to rural areas, and direct driving forces that explain this problem more clearly, such as the extent of the geographical dispersal of potential consumers that currently lack access to electricity, might well be inferred from regional demographic density levels.

Power Rates

Regarding electricity use, there are various ISED Indicators that cover this energy source specifically. For instance, of particular importance for the high-priority areas listed in this study are the ISED Indicators # 3 (end-use energy prices). For this group of indicators, which constitute indirect driving forces in the economic dimension, electricity rates were surveyed and adjusted according to the study methodology, for end-consumers in the industrial and residential sectors. This survey showed that during the period under analysis, the rate for electricity acquired by Brazil's residential sector (not including taxes charged on the rate) was on average at least twice as high as the rate for the industrial sector (See Figure 3.16). As the tax is charged as a percentage of the electricity rate, this difference between the rate values becomes even greater in absolute terms.

[40] These estimates are in line with the results of the pilot study undertaken by Schechtman el al (1996).

Figure 3.16. Power Rates – ISED # 3
Source: Eletrobras, 2001

Among other reasons, this difference in values derives from the way in which electricity is contracted by the various consumption sectors, depending on the supply voltage and the contracted demand. For Brazil's residential sector, a "conventional" rate system is used, characterized by electricity use and/or capacity demand rates that are not scaled by times of use during the day and seasons of the year. In the case of the industrial sector, the "hourly/seasonal" rate is used, with consumption and demand rates scaled to times of use in the course of the day (peak and off-peak periods) and the months of the year (dry season: May − November: wet season: December − April).

More important still were the historical incentives benefiting electricity-intensive industrial sectors over the past two decades, such as primary aluminium production. Mainly commodity exporters, these sectors are affected to a considerable extent by lower electricity rates. Within this context, they were able to purchase electricity at prices slashed to 25% of the average electricity price acquired by other consumption sectors in Brazil.

Another important issue underlying the electricity rates charged to the residential sector is the link between the historical dynamics of this rate (which dropped considerably in the mid-1980s to almost 60% of the rate at the start of the decade), and the lack of electricity conservation incentives among consumption sectors. The drop in the rate levels implemented in Brazil reflected the anti-inflation policies introduced by the Brazilian Government. But there was a counter effect that weakened the self-financing capacity of the power sector, particularly the start-up of operations of large-scale hydropower plants whose operating costs were relatively low.

In turn, during the 1990s, two milestone events were noted for establishing the end-prices of electricity: the Disequalization Act (1993) which eliminated the regional homogenization of electricity rates, and the reform of Brazil's power sector, whose beginning can be related to the establishment of the National Electricity Regulatory Agency (ANEEL) in 1995. In general, contrasting with the 1980s, a steep increase in electricity rates was noted in the residential sector from 1995 onwards; the 2000 rate was 37% higher than the figure for 1995. It is interesting to note that this rate increase coincides with (and is partially explained by) the restructuring of the power sector, falling far more heavily on the residential sector than the industrial sector (from 1995 through 2000, the rate for the latter sector only rose 12%).

Moreover, the power supply rate in 1991 (including the electricity imported from the Itaipu Hydro-Power Complex) represented 67% of the average final rate for all energy consumption sectors in Brazil, but from 1995 onwards this proportion shrank considerably to around 40%. In brief, from 1995 onwards, the power supply rate began to remunerate the distribution utility more than the power generation one, with this

increase falling more heavily on the residential sector. Oddly enough, one of the benefits of the Real Economic Stabilization Plan launched in 1994 – which introduced Brazil's new currency – was expanding ownership of household appliances among the lower-income classes. However, the increase in rates offsets this benefit. Another interesting point in these data is their link to the privatization of Brazil's power utilities, focused mainly on the distribution side. To some extent, the recovery of rates during the 1990s affected the residential market more heavily, because it is more widely dispersed, benefiting the power distribution utilities instead of expanding Brazil's power generation segment.

Energy Intensity[41]

Figure 3.17 presents overall final energy use, GDP (producers' prices) and final energy intensity indicators for the Brazilian economy through the last three decades (ISED Indicator #9). It may be verified that both the final energy use and the GDP (producers' prices) of the Brazilian economy grew more than three and a half times during the 1970-2000 period. Furthermore, one might observe that both indicators, final energy use and the GDP (producers' prices), are highly correlated in the last 30 years[42]. As a consequence, the final energy intensity of the Brazilian economy coefficient was considerably stable through the whole period. However, starting in 1980 a net increasing trend is observed in the overall final energy intensity.

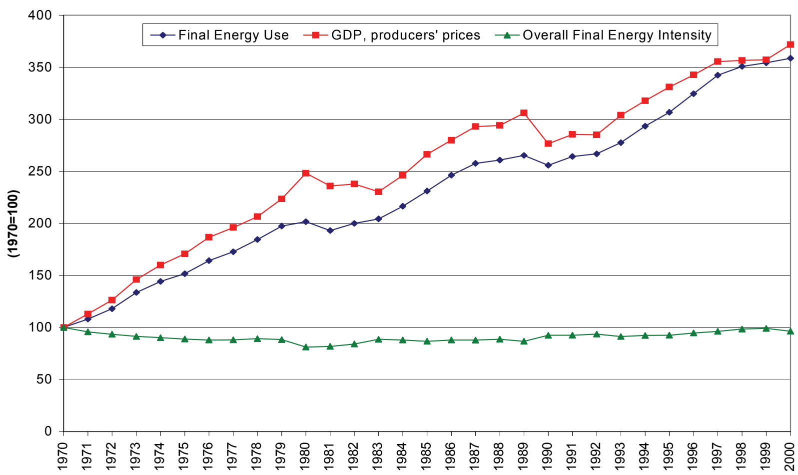

Figure 3.17. Final energy use, GDP at producers' prices and final energy intensity of the Brazilian economy – ISED # 9 Source: MME (2001), IBGE (2002), IPEADATA(2002, 1994) and World Bank (2003).

The results for the ISED Indicator #12 (Energy Supply Efficiency) show that the ratio of final energy to TPES for the Brazilian energy system is relatively high and remained steady throughout the past two decades under analysis (Table 3.20). The relatively high efficiency is the result, to a certain extent, of the predominance of hydro-based power generation in Brazil. This indicator shows a similar trend to that of the overall energy intensity of the economy shown in Figure 3.17. These aggregated data, however, do not provide sufficient insights about energy intensity changes at the sectoral level. Therefore a decomposition method (Park, 1992) was used to help identify the factors affecting final energy use in the Brazilian economy.

[41] This section is based on chapters 2 and 5 of Brazil: *A country profile on sustainable energy development*, (IAEA et al., 2006).

[42] Statistical correlation does not necessarily imply any causal relationships, however.

TABLE 3.20. FINAL ENERGY TO TPES ISED # 12

Year	%
1980	83.8
1985	82.6
1990	83.3
1995	84.7
2000	83.8

Source: Based on MME (2001)

Figure 3.18 displays the results of the energy use decomposition analysis for the Brazilian economy from 1970 to 2000, divided into periods of five years. It shows the basic effects (activity, structural and intensity) and the term of interaction.

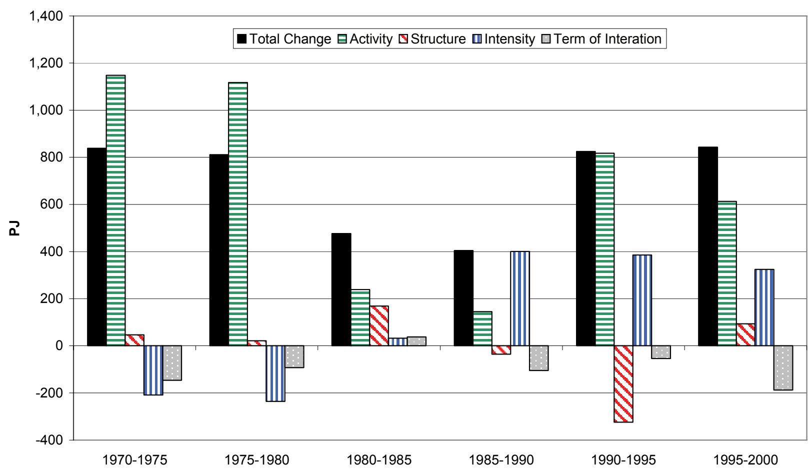

Figure 3.18. Decomposition of energy use changes in the Brazilian economy
Sources: MME (2001), IBGE (2002), IPEADATA(2002, 1994) and World Bank (2003).

Figure 3.18 shows that usually the activity effect (economic and demographic growth) was the major effect behind energy use changes in the Brazilian economy through the 1970-2000 period (except for the 1985-1990 sub-period). The analysis of the contribution of the activity effect to energy use changes in Brazil shows that, similarly to any other country, everything else remaining the same, higher economic growth leads to higher energy use. Nevertheless, "everything else" usually does not remain the same: changes in the structure of the economy and intensity effects might magnify or offset the activity effect. Thus, a fundamental task to help decipher the energy use of a country is to further analyse how "everything else" is evolving.

Looking at Figure 3.18 again, it is possible to observe that the structural effect was negligible during the sub-periods of 1970-1975 (46 PJ), 1975-1980 (21 PJ) and 1985-1990 (-36 PJ), modest during the 1995-2000 sub-period (94 PJ), but relevant during the sub-periods of 1980-1985 (168 PJ) and 1990-1995 (-324 PJ). In addition, it is possible to observe that the intensity effect was negative during the 1970s and positive through the 1980s and the 1990s.

To understand better the trends behind the intensity effect results, Figure 3.19 shows the evolution of final energy intensity by sector (Agriculture, Industry, Services) and the Economy as a whole. Differently from the overall final energy intensity indicator, it can be verified that in the long-term all the intensities show relative increasing trends. All sectoral final energy intensity trajectories presented in Figure 3.19 experienced fluctuations, resulting either from changing sectoral trends or from conflicting intra-sectoral trends.

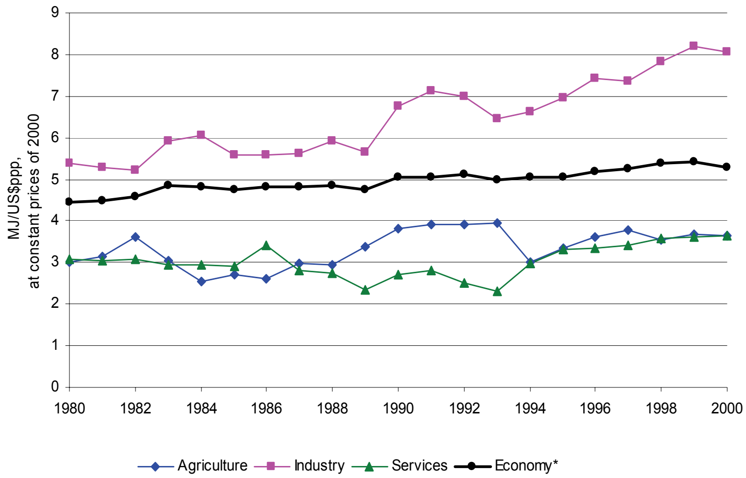

Figure 3.19. Evolution of overall and sectoral final energy intensity indicators – ISED #9
Sources: MME (2001), IBGE (2002), IPEADATA (2002, 1994) and World Bank (2003)
*Note: * Economy excludes household Sector. Non-energy use is not included.*

In sum, it is possible to say that the overall economic growth of Brazil was the most important effect influencing energy use changes in Brazil during the 1970-2000 period as a whole, either to push it up (1970-1975, 1975-1980, 1990-1995 and 1995-2000) or to push it down (1980-1985 and 1985-1990). Nonetheless, structural and intensity effects have also influenced the energy use change of the Brazilian economy significantly during the last three decades. In this sense, a strategy to enhance energy sustainable development in Brazil should consider not only the impact of economic growth on energy use, but also the influence that structural changes and sectoral final energy intensity might have on energy use.

To understand better the trends behind the intensity effect results, it is important to look at the evolution of final energy intensity by industrial branch. It can be verified that the Industry's final energy intensity registered an upward trend in the 1970-2000 period as whole (0.4% per year). As a matter of fact, if one breaks the 1970-2000 period down, different trends emerge. In the 1970-1975 period, the Industry's energy intensity actually decreased at 5.0% per year and 0.2% per year in 1975-80, while it increased at 0.7% per year in 1980-1985, 3.9% per year in 1985-1990, 0.5% per year in 1990-1995 and 3.0% per year in 1995-2000.

Finally, an important fact of the 1990s was related to incentive economic policies designed to guarantee the international competitiveness of semi-finished goods exports and to the lack of adequate institutional supports for promoting dynamic competitiveness. Owing to this fact, export-focused industrial sectors, such as Iron & Steel and Pulp and Paper, have shown a shift to less-value added goods in the mix of their industrial output. Interestingly enough, such an intrasectoral product mix change is usually mistaken as a technical effect by the country's statistics. In the case of pulp and paper, the trend was the reduction of paper's share in total output. For metallurgy, the trend was the increased production of pig iron, primary aluminium and semi-finished goods.

On the other hand, Transportation registered final energy intensities of 47.0 MJ/US$ppp, 2000 prices in 1970, 35.8 MJ/US$ppp, 2000 prices in 1980, 42.2 MJ/US$ppp, 2000 prices in 1990 and 73.3 MJ/US$ppp, 2000 prices in 2000. Such a trend seems to be related to an energy efficiency program in the 1980s (CONSERVE Program), inter-mode substitution towards freight road transportation and towards private transportation (away from passenger public transportation) and a fall in value added (tariff control and deterioration of public transportation system reinforcing preferences for private and alternative transportation).

Electricity Intensity

The electricity intensity evolution (see Figures 3.20 and 3.21) did not follow the per capita GDP contraction of the 1980s and the slight per capita GDP expansion of the 1990s, because:

- The expansion of electricity-intensive industries was strongly promoted by the Brazilian government during the 1980s. These industries account for a large share of the industrial electricity use but for a small share of its output. Aluminium, iron, cement, petrochemical, chlorine, and pulp and paper manufacturers represented 27% of Brazil's total electricity use as of 2000 (MME, 2002a), while their contribution to the GDP value added was less than 8%.[43]
- Since 1979, the Brazilian government has been promoting the modernization of the agricultural sector, focusing mainly on two different sets of goods: export-oriented primary crops and fruits, and biomass for energy purposes. In addition, the Rural Electrification Program launched in 1999 also affected the use of electricity by medium and small Brazilian farms.
- Electricity use grew considerably in the household sector, mainly owing to the urbanization process and the increasing access to the electricity grid.
- During the 1980s, Brazil's government took actions designed to curb inflation, imposing tight controls on tariff levels. This stimulated industrial and household electricity use.
- Finally, electricity commercial losses increased in Brazil (See Figure 3.22). These losses were driven by the increased number of clandestine hook-ups made by households in slums and by ventures of the informal economy.[44] Both ventures of the informal economy and households in slums increased during the 1980s. Interestingly enough, the informal economy increases electricity use but is not accounted for in the GDP, meaning that it increases the electricity use intensity by either the commercial losses or the underestimation of the GDP.

[43] Since 1980, electricity-intensive industrial sectors have accounted for more than 45% of industrial electricity consumption. By 2001 these sectors accounted for 99.8% of the industrial electricity consumption in the Northern region, 39.9% in the Southeast, and 45.8% throughout the country (CCPE, 2003).

[44] Informal economy includes the underground activities that have legal ends but employ illicit means. These activities do not intrinsically have a criminal content, but must be carried out illicitly, even though they are licit and desirable activities for the country. In general, the informal economy includes street vendors, labours for less qualified services, and small-scale manufacturers. For instance, the street vendor is a merchant with licit goals, but illicit means, because of non-compliance with legal regulations and labour laws, and the non-payment of taxes.

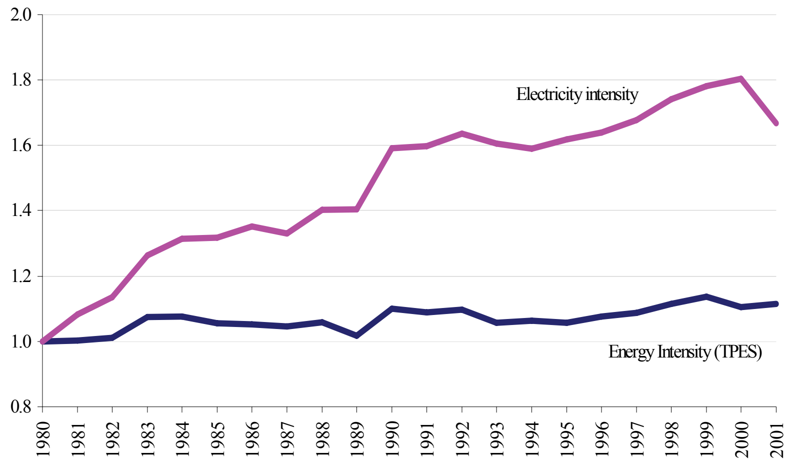

Figure 3.20. Energy and Electricity Intensity – ISED # 9 and # 10
Source: Based on Schaeffer et al., 2002 and on World Bank (2003) for the exchange rate used.
Note: In 1980, the TPES intensity was 0.187 toe/1,000US$-ppp2000, and the electricity intensity was 0.204 kWh/US$-ppp-2000.

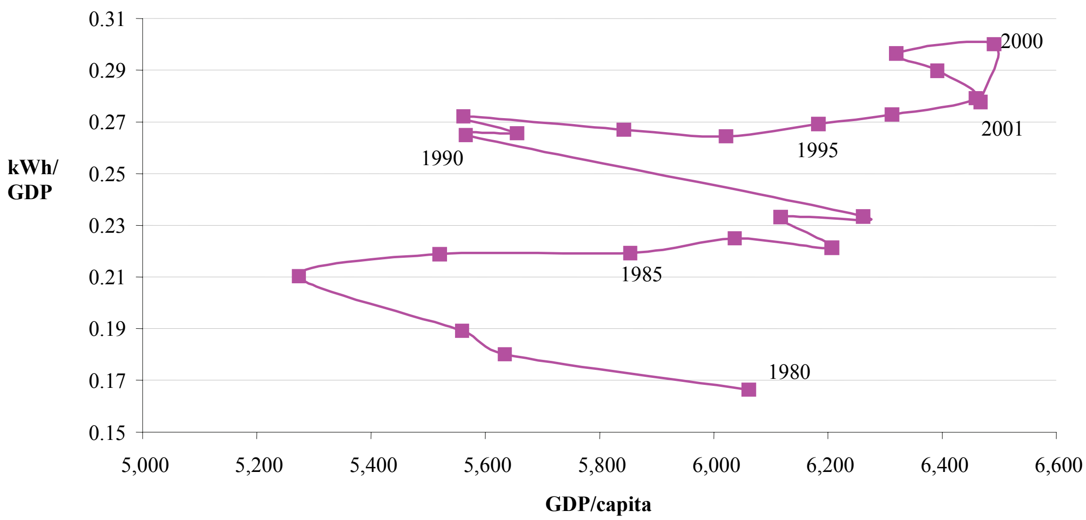

Figure 3.21. Electricity Intensity and GDP per capita
Source: Szklo and Cunha (2005)
Note: GDP in US$ ppp-2000.

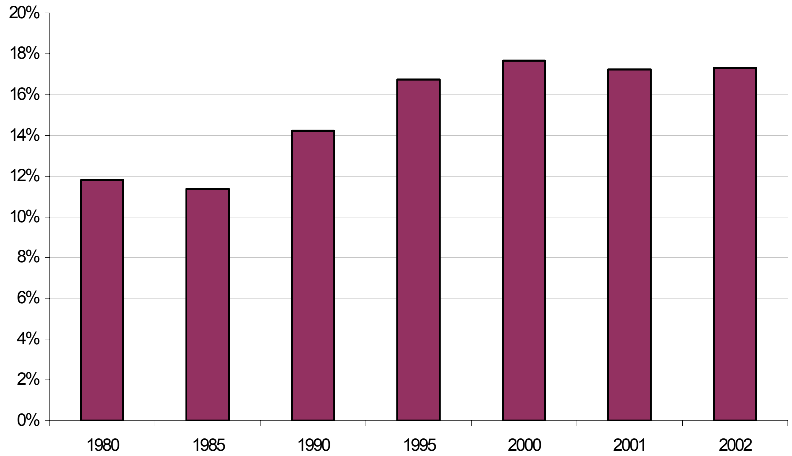

Figure 3.22. Electricity Losses – ISED #12
Source: MME, 2003.

Per capita energy consumption

On the other hand, the per capita energy intensity indicator initially leads to the conclusion that there has been some shrinkage in this indicator over the past two decades, owing to the increase for electricity and LPG, counterbalanced by a drop in fuelwood and lighting kerosene in the energy consumption mix for this sector (see Figure 3.23).

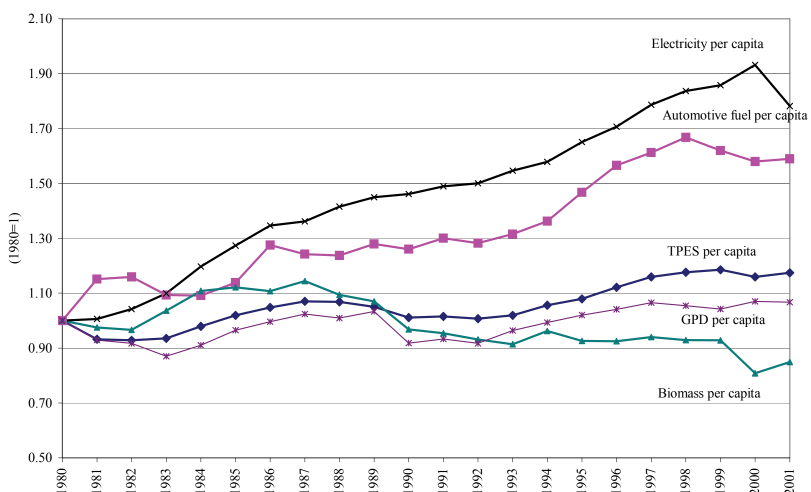

Figure 3.23. Energy per Capita – ISED #16
Sources: MME, 2002a; IBGE, 2003a, World Bank, 2003
Notes: In 1980, per capita total electricity consumption was 3,631 MJ; per capita total biomass consumption was 12,318 MJ; per capita automotive fuel consumption was 7,726 MJ, per capita TPES was 39,554 MJ, and per capita GDP was 6,062 US$-2000 ppp.

The findings also indicate a somewhat "repressed energy demand" in Brazil's residential sector, characterized by striking regional and social disparities. Although the total energy intensity of the residential sector dropped over the period under consideration, intensity based on "modern" energy sources such as electricity and oil products rose significantly over the period, reflected in the considerable shrinkage in the use of fuelwood, which to a certain extent is also related to the increase in the urban population of Brazil, as already discussed in this document.

However, per capita electricity consumption by Brazil's residential sector is still relatively low and very heterogeneous throughout the country. For instance, the per capita electricity consumption in the Southeast region is twice the level noted in the Northeast region. Once again, this fact underscores Brazil's regional

disparities and the potential increase in energy consumption by the residential sector as a whole. It also indicates that the more available income among the poorer sectors of the Brazilian population may well result in a propensity to consume electricity among a considerable portion of the Brazilian population, resulting in a substantial improvement in the quality of life.

This type of analysis also denotes a strong link between the two priority areas identified here for the sustainable development of the Brazilian energy system. On the one hand, "promoting energy efficiency whilst reducing regional disparities and improving energy affordability" means both a reduction and an increase in primary energy sources use[45]. On the other hand, on the energy supply side, an increase in energy use among the lower income classes – assuming that this increase would not reflect improper use of energy resources but rather better access to basic energy services – is a challenge for the strategy designed to "diversify the energy mix, mainly by promoting the use of renewable resources".

3.5.2.2. Environmental Dimension

Local Pollutants

The high-priority areas defined in this study failed to clearly explain the environmental impacts of atmospheric emissions produced by Brazil's energy system. The need to avoid or prevent these impacts was implicit in the objectives of diversifying Brazil's energy mix through renewable sources while enhancing energy efficiency. To characterize these impacts, this study obtained data for the ISED Indicators 23, 26, 40 and 41.

For ISED Indicator 23 (Quantities of Air Pollutant Emissions), an analysis of the SO_2 findings showed that most of the historical emissions deriving from fossil fuel use lie within the industrial sector (see Figure 3.11 in Section 3.1).

This is owing to three main factors:

- first, the energy use profile of this sector, with major segments consuming considerable amounts of waste oils with high sulfur content levels and segments with significant coal products use, such as steel-making;
- second, Brazil's power generation sector, where hydro-based generation predominates, supplemented to a minor extent by power generation fuelled by coal, diesel oil, biomass and waste oils;
- finally, looking at the emissions by the transportation sector, it is worthwhile noting a considerable drop in these emissions from 1997 onwards, owing to Brazil's diesel oil upgrade program. Moreover, sulfur emissions by automobiles running on pure ethanol in Brazil have been eliminated since the implementation of the National Fuel Alcohol Program, resulting in a double dividend. Consequently, the use of ethanol indirectly paved the way for the introduction of engines fitted with catalysts.

Similar to SO_2, a significant portion of the NO_x emissions produced by Brazil's energy system takes place in the industrial sector, owing mainly to the high temperatures of its boilers and furnaces (see Figure 3.12). In the power sector, NO_x emissions by diesel engines driving stand-alone systems are particularly noteworthy, while automotive diesel emissions are noticeable in the transportation sector, followed by gasoline and automotive ethanol emissions. Particularly important over the past two decades for NO_x emissions produced by energy biomass are charcoal and sugarcane bagasse consumed by the industrial sector, fuelwood burned by the residential sector and automotive ethanol. In terms of expectations, increased participation by the electricity sector in these emissions is expected, with the start-up of

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[45] This is a crucial distinction for this study, because access to commercial energy sources does not necessarily ensure efficient supplies of the energy-base services required by the poorest segment of the population. An interesting example of this issue was identified by Schechtman et al. (1996) in a pilot survey on fuelwood and LPG consumption in rural areas in Rio de Janeiro State, which is Brazil's largest producer of oil and associated gas. This survey noted that there was a progressive shift from LPG consumption to gleaned fuelwood (i.e. non-commercial use) in the course of the month among lower income classes.

operations by the thermal-power plants and the cogeneration plants fuelled by natural gas, resulting in significant emissions of nitrogen oxides.

Global Pollutants

According to ISED Indicator 26 (Quantities of GHG Emissions from Energy-Related Activities), most greenhouse gas emissions deriving from energy consumption and production are related to CO_2. For the period under analysis, total GHG emissions rose by an average of 1.20% p.a. Compared to emissions in 1990, the 2000 emissions are 22% higher. These emissions will tend to increase even more, as renewable charcoal is replaced by metallurgical coking coal and to a greater extent by the expansion of Brazil's power generation industry, based on thermal-power plants fuelled by natural gas.

The results also showed that, although greenhouse gas emissions rose over the period under analysis in absolute terms, total per capita GHG emissions dropped slightly (see Table 3.21).

TABLE 3.21. ANNUAL CO_2 EMISSIONS PER CAPITA RELATED TO BRAZIL'S ENERGY SYSTEM ISED # 26

Year	t CO_2 eq/capita
1980	2.19
1985	2.02
1990	1.88
1995	1.83
2000	1.98

Source: Based on MME (2001), ANEEL (2002), Schechtman et al. (1998), ABRACAVE (2002), Aquino(1999), Schechtman et al. (1996), IPCC (2001).

This renewable mix places Brazil in a favourable position in terms of greenhouse gases emissions. For instance, in 1998, Brazil's energy use per capita CO_2 emissions reached 1.94 tCO_2 /inhabitant (carbon dioxide only), which is lower than the average global figure and the average figure of the OECD countries, at 3.89 and 10.93 tCO_2/inhabitant, respectively, this same year.

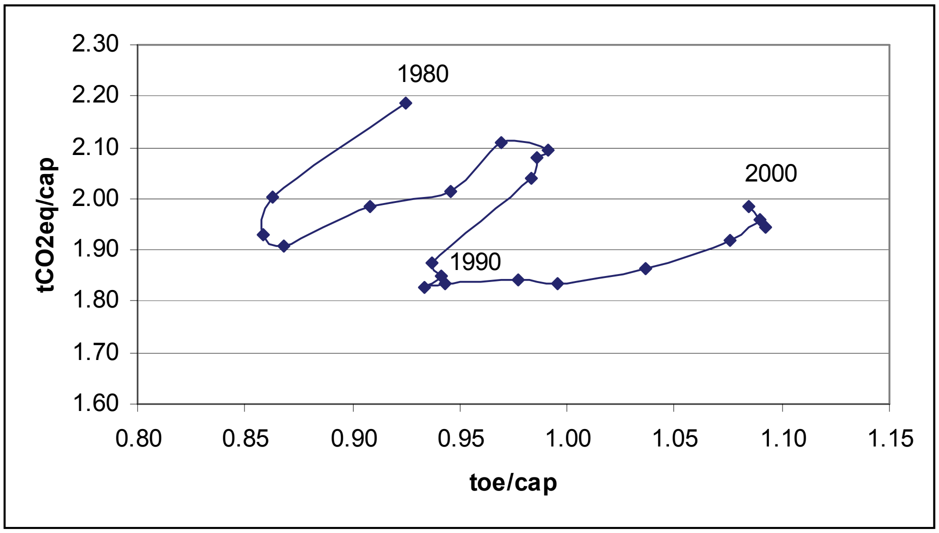

Figure 3.24. GHG emissions per capita versus TPES/capita
Source: Szklo and Cunha, 2005

Figure 3.24 indicates that total per capita GHG emissions were implicitly influenced by the country's economic development, and by specific driving factors related to the country's energy system.

The commissioning of large hydro-power plants[46] in the first half of the 1980s was followed by an economic crisis that created temporary imbalances between the electricity supply and demand, and by governmental policies promoting electricity-intensive industries and electric heat generation.

From 1982 to 1986, some specific industrial sectors, which concentrate fossil fuel industrial consumption in Brazil, recovered their economic activity. For example, the average growth rate of the iron and steel and the chemical sectors between 1982 and 1985 was 13% and 11% (value added), respectively. These sectors account for a significant share of the GHG emissions in Brazil.

Between 1986 and 1991, industrial activity reduced considerably, especially for those fossil-fuel intensive segments noted above: the iron and steel sector value added decreased 6% p.a., and chemical sector value added decreased 3% p.a. On the contrary, electricity use kept increasing at high rates and ethanol use in the transportation sector reached its apogee.

Finally, since the 1990s (and especially after 1995, the year after the price stabilization), economic activity rebounded. In addition, in the 1990s, specific policies increased fossil fuel use in Brazil. First, incentives given to the export of semi-finished industrial goods promoted export-oriented industrial segments, which also represent a major share of the fossil fuel industrial use; second, the ethanol supply crisis of 1989 and the discontinuation of the Ethanol Incentive Fuel Program during the 1990s promoted inter-fuel substitution in the transportation sector, increasing fossil fuel use.

The intensity of CO_2 emissions per GDP for the energy system, which is another finding drawn from ISED Indicator 26 (see Table 3.22), is also lower in Brazil than in the industrialized countries. While emissions deriving from energy transformation and use in Brazil brought this Indicator to 0.36 kg CO_2/US$90 (ppp) in 1998, worldwide and in the OECD countries, this Indicator reached 0.66 and 0.62 kg CO_2/US$90 (ppp), respectively (Oliveira, 2001).

[46] There is still much uncertainty over GHG emissions by hydropower plants. For this aspect, see Rosa et al. (1996) and Rudd et al. (1993). However, according to the preliminary estimates, except in a very few cases, GHG emissions from hydropower plants are far lower (in fact, almost negligible) than those produced by their thermo-power counterparts burning fossil fuels (Rosa et al., 1996).

TABLE 3.22: ANNUAL CO_2 EMISSIONS PER GDP RELATED THE ENERGY SYSTEM ISED # 26

Year	t CO_2 eq/1,000 US$-1990 ppp
1980	0.45
1985	0.40
1990	0.38
1995	0.34
2000	0.35

Source: Based on MME (2001), ANEEL (2002), Schechtman et al. (1998), ABRACAVE (2002), Aquino (1999), Schechtman et al. (1996), IPCC (2001).

Analysing Brazil's GHG emissions by energy use sectors, it is quite clear that the emissions by the power sector are minor in retrospect, owing only to thermal-power generation fuelled by coal, diesel oil and heavy oils. From 1980 through 2000, the electricity sector produced only 2.6% to 7.7% p.a. of the total GHG emissions resulting from energy use in Brazil, with the transportation and industrial sectors together accounting for almost all GHG emissions deriving from energy use in Brazil[47]. The rate of increase in the emissions by the transportation sector was far higher during the 1990s than during the previous decade, owing basically to the virtual elimination of new automobile sales fuelled solely by ethanol during the 1990s. While new models fuelled by alcohol accounted for 96% of automobile sales in 1985, they reached less than 0.5% by the end of the 1990s (Poole et al., 1998).

Finally, although the use of fuelwood as an energy source tends not to be the driving force behind deforestation in Brazil (as discussed in Section 3.1.1.1 of this chapter during the estimation of ISED Indicators 40 and 41), deforestation is still the main cause of Brazilian carbon dioxide emissions. A recent series of studies on greenhouse gas emissions in Brazil for the period of 1990-1994 rates land use changes and forestry, energy, and soils and liming, in this order, as the most important sources of carbon dioxide emissions in the country (MCT, 2002). New forest plantings, mainly eucalyptus and pine, constitute the most important carbon dioxide sinks in this sector (see Table 3.23).

TABLE 3.23. BRAZIL: CARBON DIOXIDE EMISSIONS AND UPTAKE - 1990-94

Source	Average per year (million tons of carbon)
Energy	75.8
Fugitive carbon dioxide emissions from coal mining and handling	0.4
Land use change (deforestation)	139.9
Soils and liming	22.2
Total carbon dioxide emissions	238.3
Removals from planted forests	11.0
Net carbon dioxide emissions (emissions minus uptake)	228.3

Source: MCT (2002).

3.5.2.3. Institutional Dimension

During the 1990s, major structural reforms were conducted in the Brazilian energy sector aiming at achieving, simultaneously, six major objectives: 1) to promote competitive pressures over segments inside industrial energy chains presenting low or even null scale and scope economies; 2) to attract private investors for expanding energy supply; 3) to diversify Brazil's energy system, mostly by increasing natural gas use; 4) to widen the access to modern energy services; 5) to guarantee minimum quality standards in energy services; and, 6) to foster the performance of energy companies. Within this context, Brazil's

[47] In terms of GHG emissions accumulated from 1980 through 2000, the Brazilian power sector accounted for 4.2%, while the transportation sector produced 30.4% of these emissions.

current institutional dimension is characterized by transition phases inside and crossing-over the main energy industrial chains. This poses uncertainties, opportunities and risks for the country's sustainable energy development.

3.6. Identification of Response Actions and Energy Policies[48]

A wide range of policy options and initiatives might pave the way for Brazil to soundly progress socially and economically, thus reaching higher standards in terms of sustainable energy development. Therefore, the fundamental division of response actions reported here focuses primarily on each priority area. Each response action unfolds into one or more energy policies that focus on specific aspects of the Brazilian energy sector. Figure 3.25 below depicts the two main priority areas identified and their related response actions. Nonetheless, there are still many other intersections amongst all strategies, and a policy strategy that addresses one priority area might well unfold indirectly into another priority.

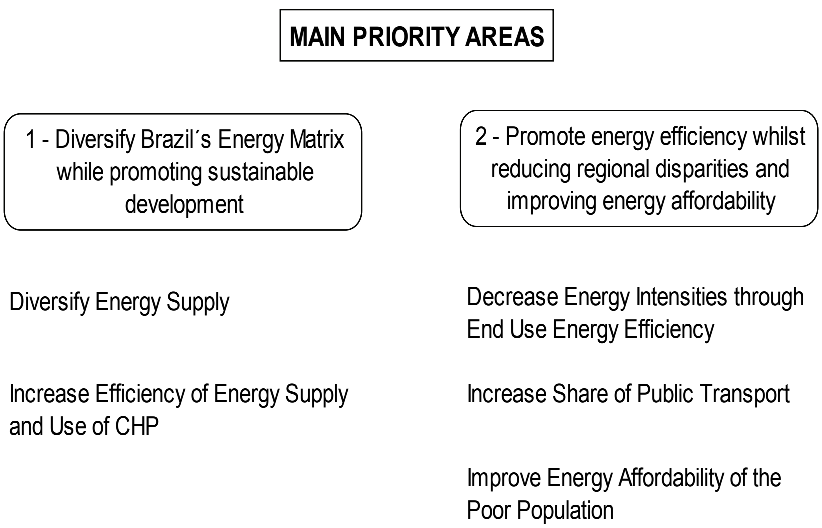

Figure 3.25. Main Priority Areas and Related Response Actions

3.6.1. Priority Area 1 and related Energy Policies

3.6.1.1. Ethanol Automotive Fuel and Sugarcane Bagasse Cogeneration

Sugar production in Brazil yields not only an important agricultural commodity - sugar - but also a renewable liquid fuel (ethanol) and a major source of biomass (bagasse) from which power can be generated.

In 1975, Brazil launched the National Alcohol Fuel Program, known as PROALCOOL, to increase the production of ethanol as a substitute for expensive and extremely scarce gasoline. Ethanol production was stimulated through a combination of policies, including: low-interest loans for the construction of ethanol distilleries, and guaranteed purchase of ethanol by the state-owned oil company at a price considered attractive for producers.

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[48] This section was partially based on Geller et al (2004) and Szklo and Geller (2005).

In spite of its sound success, the PROALCOOL ethanol fuel program has had major setbacks (as discussed in Section 3.1). The most likely scenario that could revamp ethanol as a fuel is the so-called flex-fuel technology, i.e., the allowance of any possible blend of ethanol and gasoline, electronically detected and adjusted as a fuel.

To avoid some of the problems the country has faced in the past, the government could create a "strategic ethanol reserve" (Geller et al., 2004). The reserve would be tapped in case of significant shortfall between supply and demand.

Bagasse cogeneration is the other major source of wealth and well-being derived from sugar-cane. Combined heat and power generation (CHP) fuelled by sugar-cane bagasse is a particular case among Brazil's distributed generation alternatives, since sugarcane bagasse is a by-product.

To promote the efficient use of bagasse in Brazil, the government could:

- Continue to develop and demonstrate more efficient technologies such as bagasse gasification and combined cycle power generation in sugar mills; or
- Provide long-term loans at attractive interest rates to sugar mills that adopt more efficient CHP technologies.

3.6.1.2. Non-Combustible New Renewable Energy Sources for Power Generation

Other energy sources have been encouraged via Government programs or policies in Brazil: for instance, Small Scale Hydropower (SSHs),[49] wind power, and solar photovoltaic energy.

In 2002, a policy known as PROINFA was announced to increase electricity generation by wind, biomass, and small-scale hydropower. In its first phase, 1,100 MW of each type of renewable power technology will receive up to 80 percent of the average retail electricity price in Brazil over a 15-year period. Also, PROINFA includes a goal of having alternative renewable energy sources (i.e., sources other than large scale hydropower) provide 10 percent of total electricity supply in Brazil by 2022. As a consequence of this policy, many new wind farms were proposed or under development as of 2002 and early 2003. Wind power is on the cusp of becoming a significant electricity source in Brazil.

Regarding solar photovoltaic energy, small amounts of solar power generated by photovoltaic panels in remote communities have long been a natural application for Brazil, easily outweighing costly solutions such as extending the traditional power grid to service a few widely-scattered consumers, or shipping in generator fuel to these remote communities.

If the PROINFA policy fails to result in a significant and orderly expansion of new renewable electricity sources, an alternative approach known as a renewable portfolio standard (RPS) could be enacted. An RPS obligates utilities to supply or purchase a specified amount of electricity from renewable sources, expressed either as a percentage of capacity or electricity sales. An RPS provides certainty that renewable energy sources will be implemented, stimulates competition among renewable energy providers, and encourages cost reductions.

[49] The SSHs are hydropower plants with an installed capacity of 1 to 30 MW and a reservoir area no larger than three square kilometers.

3.6.1.3. Develop and stimulate the adoption of new biomass sources

The following policies could be adopted to promote both the production and use of vegetable oils and biodiesel fuel in Brazil:

- To continue developing the application of ethanol infrastructure for biodiesel. Such a move is of special interest given the strong existing infrastructure dedicated to ethanol.
- To continue investing in R&D on vegetable oil productivity and crop diversification, thus avoiding significant dependence on only a single biodiesel vegetable oil source (e.g., soy bean oil).
- To enhance the profitability and attractiveness of the whole biodiesel economic chain via the creation of markets for by-products of biodiesel.
- To implement either time- or quantity-bound fiscal incentives to spark the development of a sustainable biodiesel industry.

These renewable energy policy options could be grouped into one response action, related to the diversification of the energy mix. To illustrate the effects of such policies, Figure 3.26 shows their correlation with the key ISED indicators presented in the previous section.

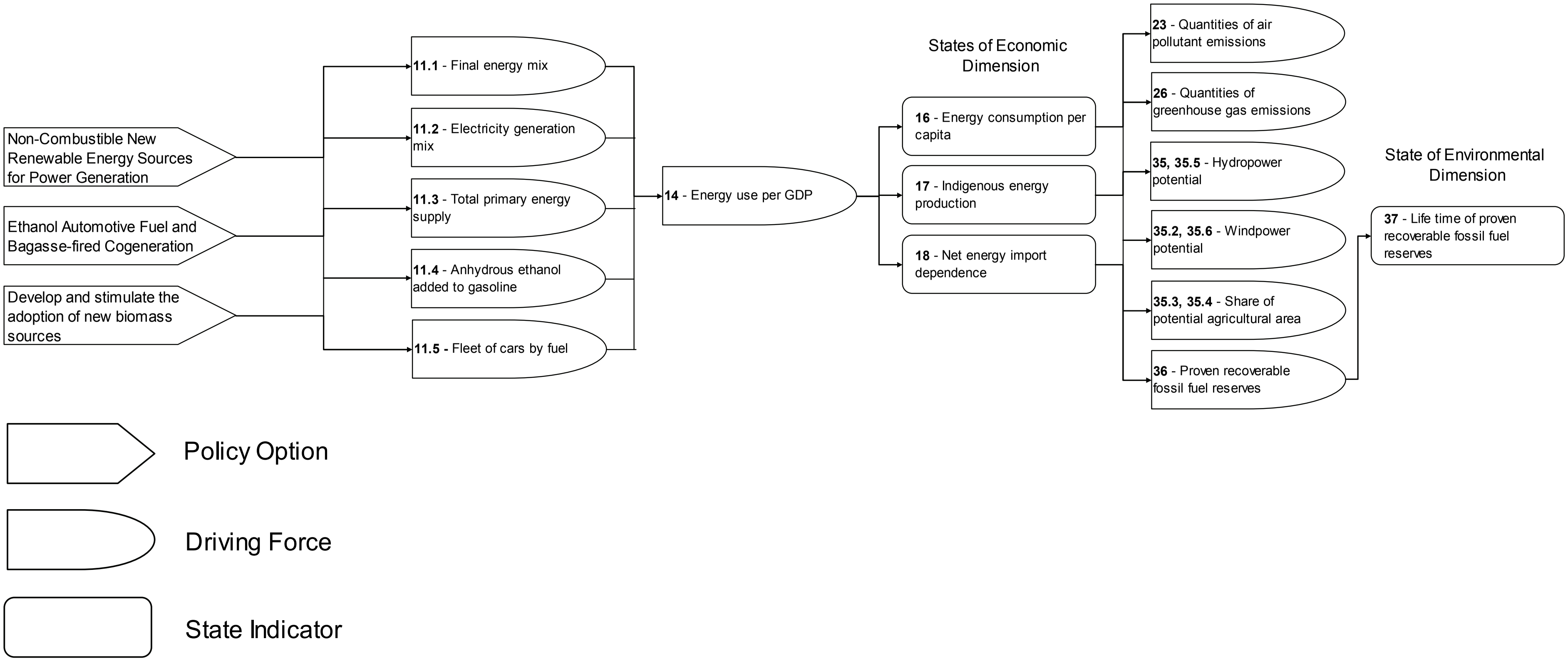

Figure 3.26. Priority Area #1 – Diversify Energy Mix – Policy Options

3.6.1.4. Lift Barriers to Natural gas CHP Implementation

Energy policy makers could implement such measures as:

- Requiring that distributors interconnect existing and future CHP enterprises to the power grid with minimum requirements, and without excessive delays.
- Encouraging energy generation efficiency, via performance-based contracting with energy service companies (ESCOs), working together with gas suppliers or electric utilities, or equipment suppliers.
- Reviewing the import taxes on CHP equipment (such as gas turbines) to accelerate the return on these investments.

This energy policy option relates to the second response action, which is devoted to the promotion of energy efficiency on the supply side through the use of CHP. Figure 3.27 below shows the links between this energy policy option and the affected ISED indicators.

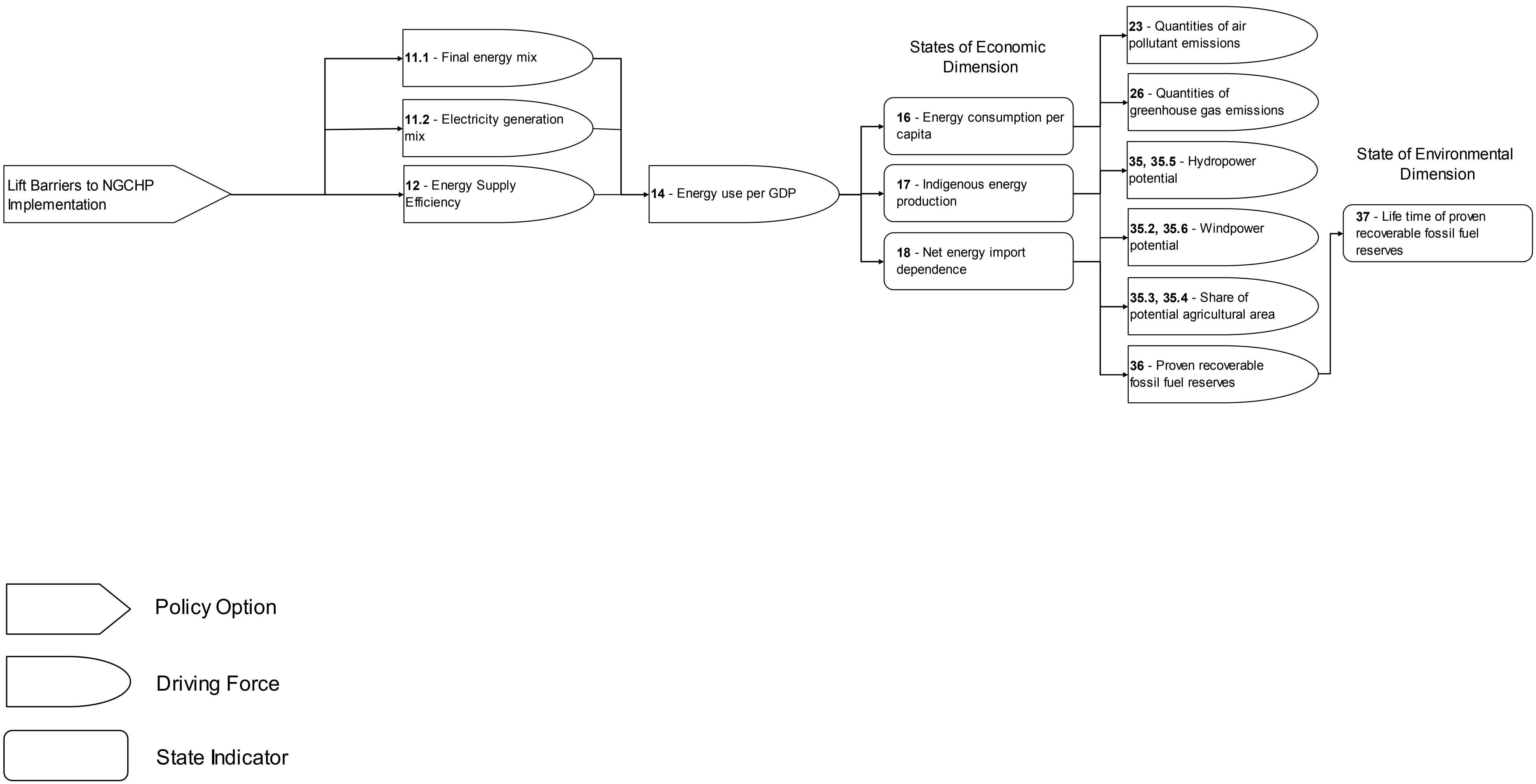

Figure 3.27. Priority Area #1 – Increase Efficiency of Energy Supply and Use of CHP – Policy Option

3.6.2. Priority Area #2 and its related energy policies

3.6.2.1. Fully Implement the Appliance Efficiency Standards Law

In 2001, a law was enacted requiring that manufacturers of certain electric-power consuming devices achieve a minimum efficiency standard. Such efficiency standards for motors were issued in 2002. Standards should also be adopted for other devices, including all new major household appliances (refrigerators, freezers, clothes washers, stoves, and air conditioners), lighting products (lamps and fluorescent lighting ballasts), and commercial sector air conditioning equipment sold in Brazil. Standards should also address the issue of standby power consumption of electronic devices such as TVs, VCRs, microwave ovens, personal computers, printers, and fax machines. The existing standards are set at the maximum efficiency levels that are technically and economically feasible.

3.6.2.2. Expand Utility Investments in End-Use Energy Efficiency

As a measure to boost end-use energy efficiency, the regulatory body ANEEL could increase the energy efficiency-spending requirement by distribution utilities to a higher level. Part of these funds could be spent directly by the utilities and part could be allocated to state and federal energy efficiency programs. Moreover, the funding could be used to support energy efficiency investments made by households, businesses, and industries; alternatively, these resources could finance energy services and help to establish the market for innovative energy efficiency measures, such as the dissemination of information, provisions for training, etc.

The regulations introduced in 1998 caused an increase in investment by utilities in energy efficiency programs. As the programs were selected, designed and implemented by the utilities themselves, much of the investment was used to reduce their energy losses, including commercial losses. Over the following years, the regulatory agency (ANEEL) gradually restricted the percentage allowed for supply side energy efficiency investments and created rules to limit the approval of loss reduction projects. As a result, since the year 2000, all regulated investments must be used for end-use efficiency programs (Jannuzzi, 2005).

The most cost effective end-use efficiency programs typically include improvements in public illumination systems (mostly changing incandescent lamps for mercury vapour and mercury for sodium high-pressure lamps), which accounted for half of the total investments. Marketing was also another area that attracted utilities' investments. However, since the year 2000, this type of project has not been allowed by the regulatory agency. Despite the recent improvements that have been achieved, there are still a number of issues that must be addressed and improved over time, such as the high costs for conserved energy; the difficulty in verifying program performance on energy saved; the duplication of programs over the years; and expenditure patterns (i.e., the high proportion of expenditure on small, uncoordinated projects) (Jannuzzi, 2005).

3.6.2.3. Adopt Industrial Energy Intensity Reduction Targets and Protocols

Highly sensitive to regulatory impositions and economically-driven incentives, industry is a key element within the overall strategy of efficiency increases on the demand side. There is significant room for achieving higher efficiency levels for fuel and electricity use within the industrial sector in Brazil. Straightforward measures include improving operating and management practices, using better equipment (such as high efficiency motors and motor speed controls), and adopting innovative industrial process technologies.

3.6.2.4. Fossil Fuel Savings

Passenger vehicles sold in Brazil are relatively inefficient because of the outdated technology employed in one-litre Brazilian engines. Most of these engines are derived from 1.6 litre-engines used to equip older models. On the other hand, vehicle production by the multinational auto manufacturers is growing in Brazil. As production expands, it would be reasonable to insist that new vehicles include a variety of fuel-efficient technologies. These standards could be expressed in terms of either an increase in fuel economy (the approach followed in the United States) or a reduction in CO_2 emissions per kilometre travelled (the approach in Europe).

In sum, Figure 3.28 shows the indicators that can positively be affected by the adoption of these energy policies.

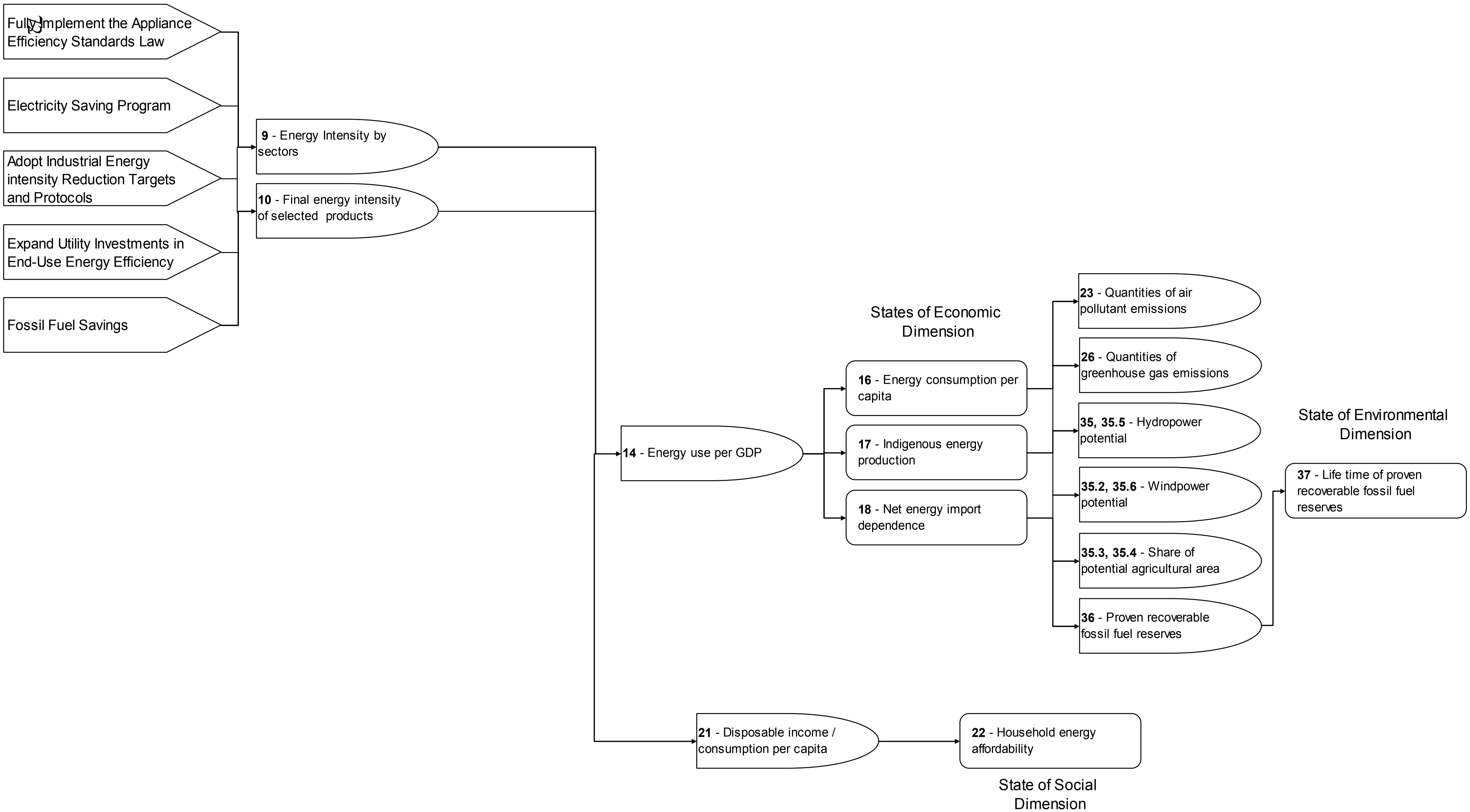

Figure 3.28. Priority Area #2 – Decrease Energy Intensity through End-Use Energy Efficiency – Policy Options

3.6.2.5. Improve the Efficiency of Passenger Transport, through Transport Planning and Shifts to Less Energy-Intensive Modes

A truly long-term sustainable and efficient transportation network can only be achieved with the foundation of coordinated urban and transportation planning policies to reduce less efficient light vehicles and fuel share in the overall transportation mix. Policy options for improving urban passenger transport systems would include the displacement of individual transportation by mass transportation through better inter-modal integrations and improved quality of service; improvement of infrastructure for buses; increases in the load factor of cars and light trucks through ride sharing and greater access of higher occupancy vehicles on major urban highways; and encouragement of pedestrian and bicycle trips through construction of dedicated pedestrian and bicycle lanes. Figure 3.29 depicts the positively affected indicators by the adoption of such policies.

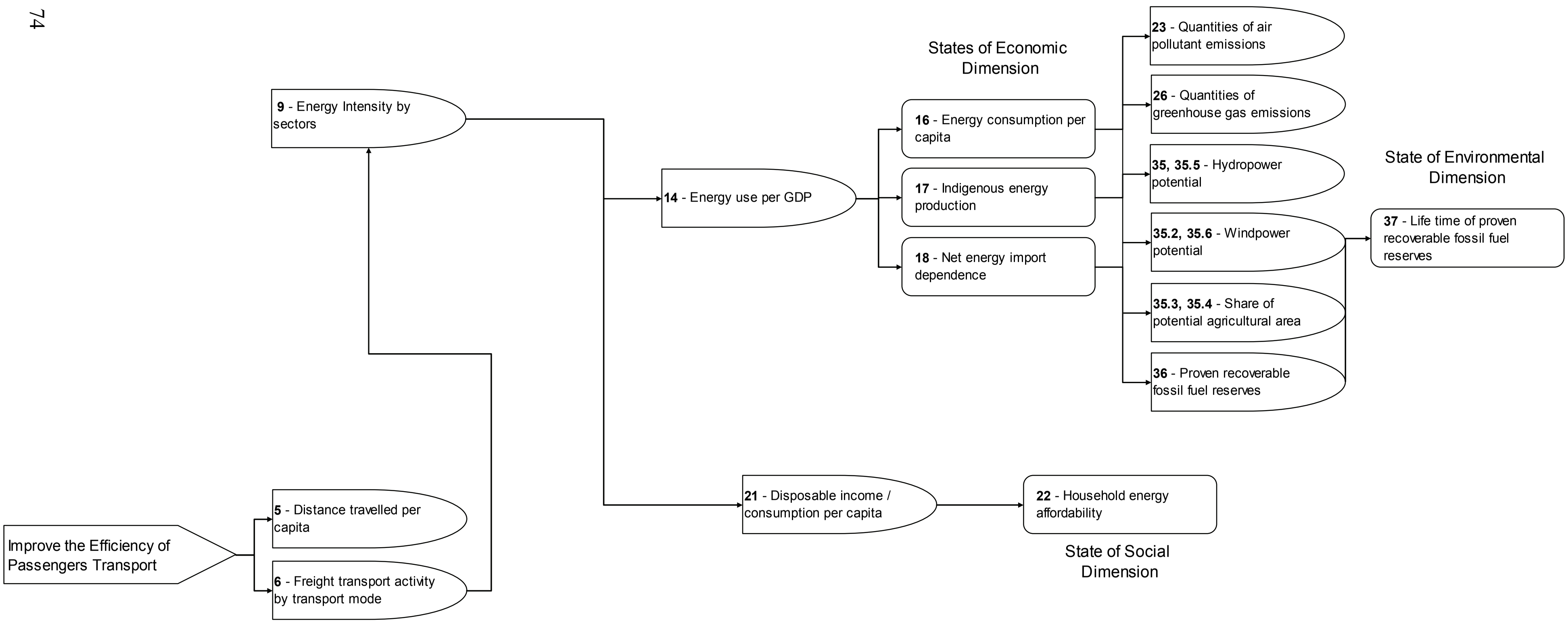

Figure 3.29. Priority Area #2 – Increase Share of Public Transport – Policy Option

3.6.2.6. Creation of a fund for helping poor people to buy energy services

To improve energy affordability for the poor, a policy would be developed to create a fund that would provide low-income segments of urban and rural areas of the country with a refund for part of their expenses on energy (e.g., gas and electricity). This fund's main financial resources would be derived from energy tariffs or from other social government funds. Different from other types of policies based on tariff differentiation among distinct energy consumption levels, this policy's primary advantage is the maintenance of a sufficiently high (real) energy price that would stimulate energy efficiency as well as improve energy affordability among low-income classes. This policy would be an extension of similar policies previously adopted in the country. However, these previous efforts proved to be isolated, and did not affect the target population owing to the lack of adequate information. Finally, Figure 3.30 shows the possible affected social indicators associated with the adoption of such an energy policy.

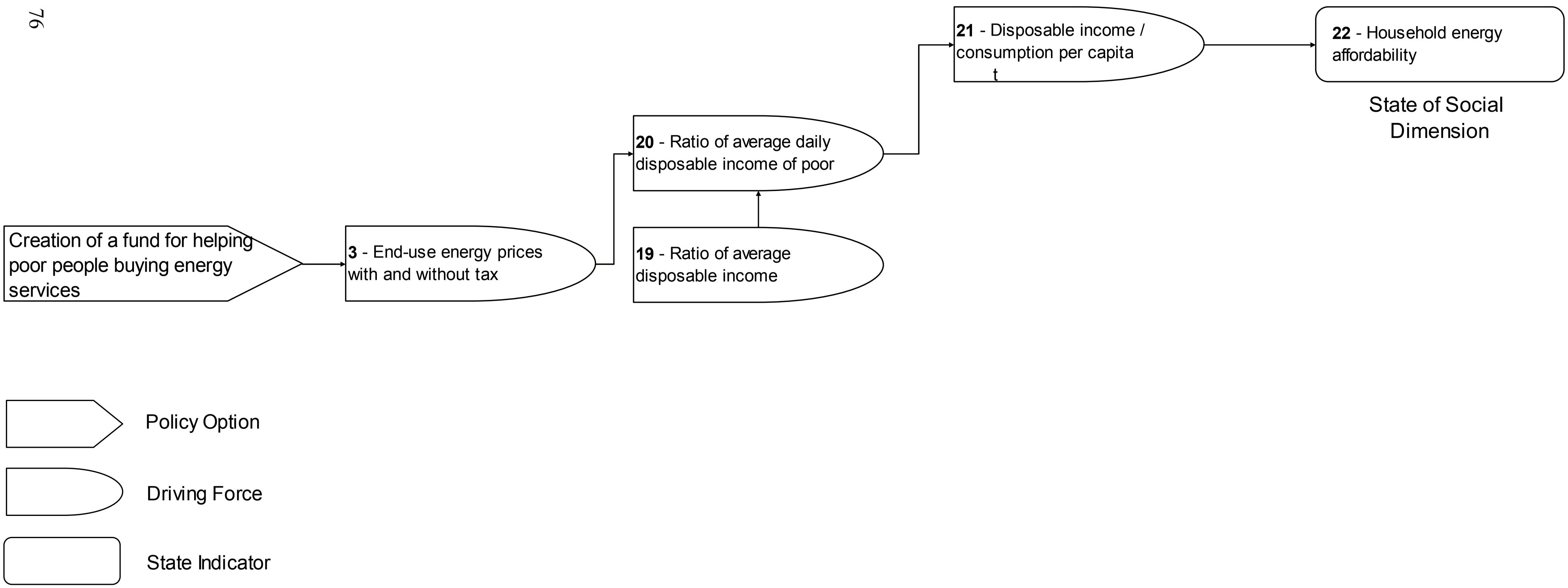

Figure 3.30. Priority Area #2 – Increase Energy Affordability of the Poor Population – Policy Option

3.7. Conclusions and recommendations

As this chapter has shown in previous sections, the ISED set of indicators is very useful for assessing Brazilian sustainable energy development. This assessment also allows the proposition of strategies for improving the use and production of energy in the country towards sustainable development, as shown in Figure 3.31.

Brazil is a country characterized by a historically high share of renewable energy in its total energy supply. Even though it is a Non-Annex I party to the Convention, and as such does not have binding commitments for GHG reductions, the country has nevertheless implemented a series of national measures over time which have resulted in even lower carbon emissions (especially for a country which already has extremely low carbon emissions by any standard). For instance, in the power generation sector, the country invested in hydropower plants; and in the fuel sector, it has implemented the largest program in the world for commercial biomass source, the Ethanol Fuel Program (see Section 3.1.1). Therefore, Brazil is an interesting case for sustainable energy development and a challenging example for the ISED set application.

However, the country's relatively favourable position regarding its GHG emissions indicators does not imply a similar situation for all dimensions of sustainable energy development. Indeed, while technical efficiency, measured by specific energy consumption, has been slightly decreasing over the past decades in almost all industrial segments, Brazil's total primary energy supply intensity has remained almost unchanged during the last two decades. This shows that inter-fuel substitution (mostly oil by hydro electricity, and fuelwood by oil products) and technical progress were compensated by the shifts to energy-intensive industries and the increased use (and ownership) of private cars during the period. Especially, the electricity intensity evolution did not follow the per capita GDP contraction of the 1980s and the per capita GDP slight expansion of the 1990s, because:

- The expansion of electricity-intensive industries was strongly promoted by the Brazilian government during the 1980s. These industries account for a large share of industrial electricity use, but for a small share of its output.
- Electricity use grew considerably in the household sector, primarily due to the urbanization process and increasing access to the electricity grid.
- During the 1980s, Brazil's government took actions designed to curb inflation, imposing tight controls on tariff levels. This stimulated industrial and household electricity use.
- Finally, electricity commercial losses increased in Brazil. These losses are driven by the increased clandestine hook-ups made by households in slums and by ventures of the informal economy. Both such user groups increased during the 1980s. Interestingly enough, the informal economy increases electricity use but is not accounted for in GDP, suggesting that it reduces the electricity use intensity by either the commercial losses or the underestimation of GDP.

In relation to the ISED, this set of indicators does not present a complete picture of the Brazilian energy system, given the income inequalities of the country and the regional disparities that reinforce these income inequalities. Within this context, the social dimension of the Brazilian sustainable energy development becomes crucial. For instance, in 1999, although the Brazilian average Gini Index was 0.567, the Paraíba state figure was 0.644, or around 30% higher than the figure of Santa Catarina State (IBGE, 2002). In addition, in 1987, 1990, 1993 and 1996, the richest 20% of the population absorbed 81% of the total income of the economically active population of the Northeast, with this proportion dropping to 68% in Southeast Brazil over these same years.

The poorest regions of the country have dwellings without access to the electricity grid. Therefore, an average figure for energy accessibility and affordability does not clearly express the heterogeneity of Brazil's various regions, and lack of access to the electric power grid is mainly a regional problem. It is indirectly linked to the concentration of the population in rural areas and to income distribution patterns among the various regions of the country – around 90% of the households lacking electricity in Brazil have an income of less than 550 U$ ppp 2000 (Tolmasquim, 2003). As major cities tend to cluster investments in infrastructure, larger scales offer network economies for public services.

Finally, aiming to assess social inequalities in Brazil's household energy use, some studies expressed how different income classes in Brazil perceive direct energy consumption (Schaeffer et al., 2003; Szklo and Cunha, 2005). In terms of expenditure, by 2000 the highest income class spent 4.3 times more for the final energy it consumed than the lowest income class. Nevertheless, that expenditure represented less than 4% of the average income of the richest income class, while it was 9% for the lowest income class (Szklo and Cunha, 2005).

Therefore, there is room for improvement in the ISED set of indicators that would be able to incorporate regional and income disparities. In fact, one of the main priority areas defined in this study concerns the reduction of regional disparities and the improvement of energy affordability. Yet, as of today, the average figures, especially when referring to the household sector, do not address these major issues of the Brazilian energy system.

Finally, Brazil's energy and economic data are only partially adequate and should be improved. The first-year progress report and Section 3.2 of this chapter identified this need, and an analysis of the suitability of data addressing sustainable development was one of the major goals of this study.

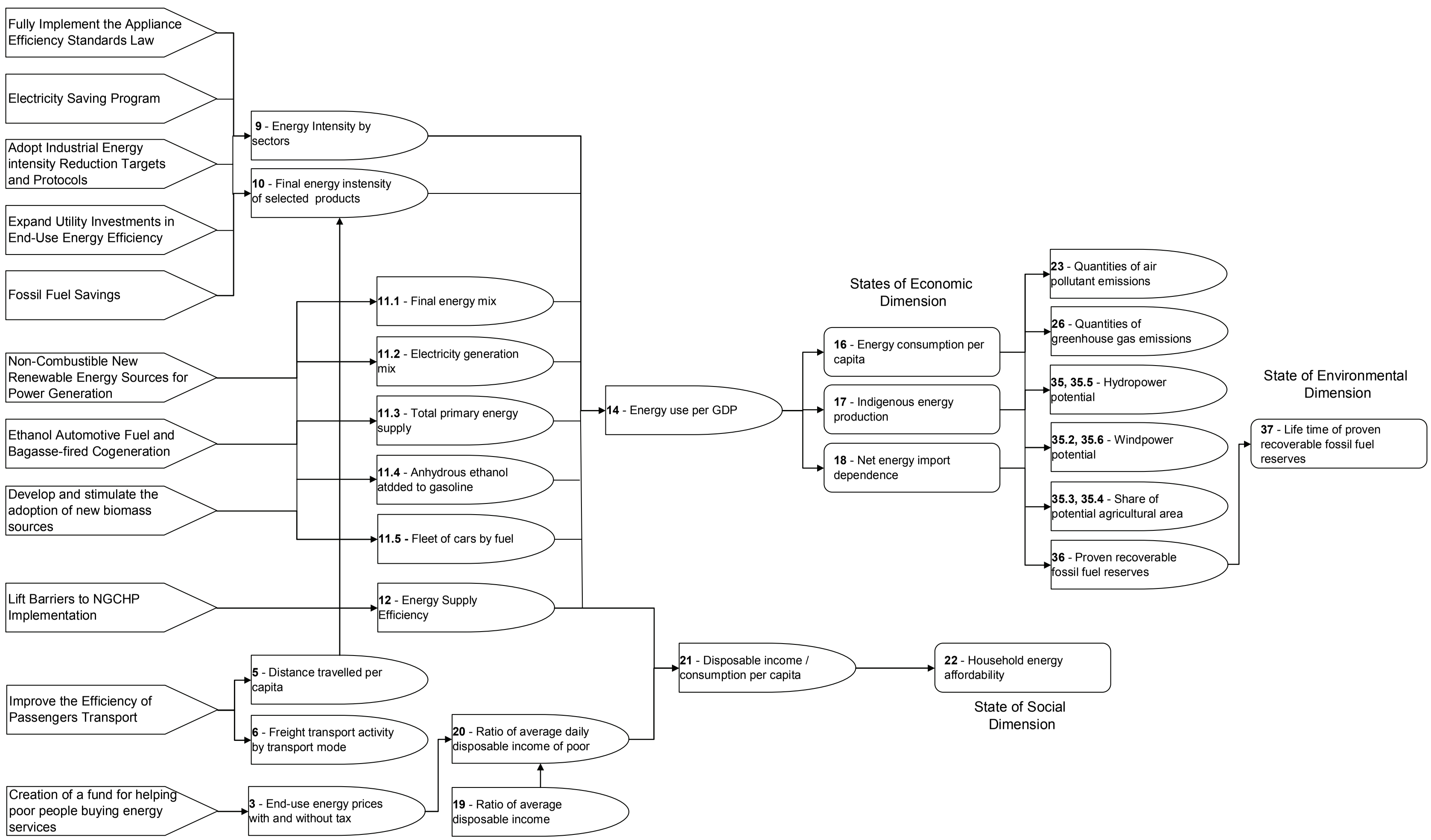

Figure 3.31. Brazil's ISED Set Map – Links between Priority Areas, Energy Policy Options and Indicators

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