ENERGY CONSERVATION AND GREENHOUSE GAS EMISSIONS IN BRAZIL

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1. Introduction

The use of energy is one of the main causes of the anthropic emissions of CO_2 [1] to the atmosphere. To reduce these emissions without diminishing welfare, the main strategies are: 1) to ***substitute*** the fossil fuels by other non emitting (renewable) sources such as hydroelectricity, solar and sustainable biomass; and 2) to ***conserve*** or to use more eficiently all forms of energy. The objective of this work is to analyze the application of the latter strategy in the Brazilian economy although, in the Brazilian context, the two themes are often strongly interrelated.

Brazil`s CO_2 emissions at present are among the lowest in world in relation to the population and the size of the economy. This situation, however, is changing and emissions have been growing in the last years, with a tendency to accelerate in the future.

At the same time, there is great potential for energy economy in end-uses: either directly using more efficient technologies in cars, motors, home appliances, lighting etc.; or indirectly, through actions like improving transportation systems. There is also significant potential to reduce energy waste in the energy supply industries, in the process of transforming primary energy into the forms used by consumers. By applying measures to effectively exploit these potentials, the rising trend in emissions can be mitigated and even reverted.

The relationship between energy conservation and reduction of emissions in Brazil is not linear, due in good part to the importance of hydro in electricity generation. However, the increase in thermal generation expected to happen in the next few years, will increase the correlation between the two at the margin.

Since the use of fossil fuels is inevitable, their efficient use and the reduction of energy losses is probably the most attractive way to reduce CO_2 emissions. The rational use of energy is a good example of a “no regrets” policy. Given the economic and social benefits, it is justifiable even if CO_2 emissions should in future not be considered a problem. The attractiveness is reinforced by the fact that maintaining or increasing the use of non emitting biomass fuels in substitution of fossil fuels in Brazil will partly depend on improvements in their transformation efficiency.

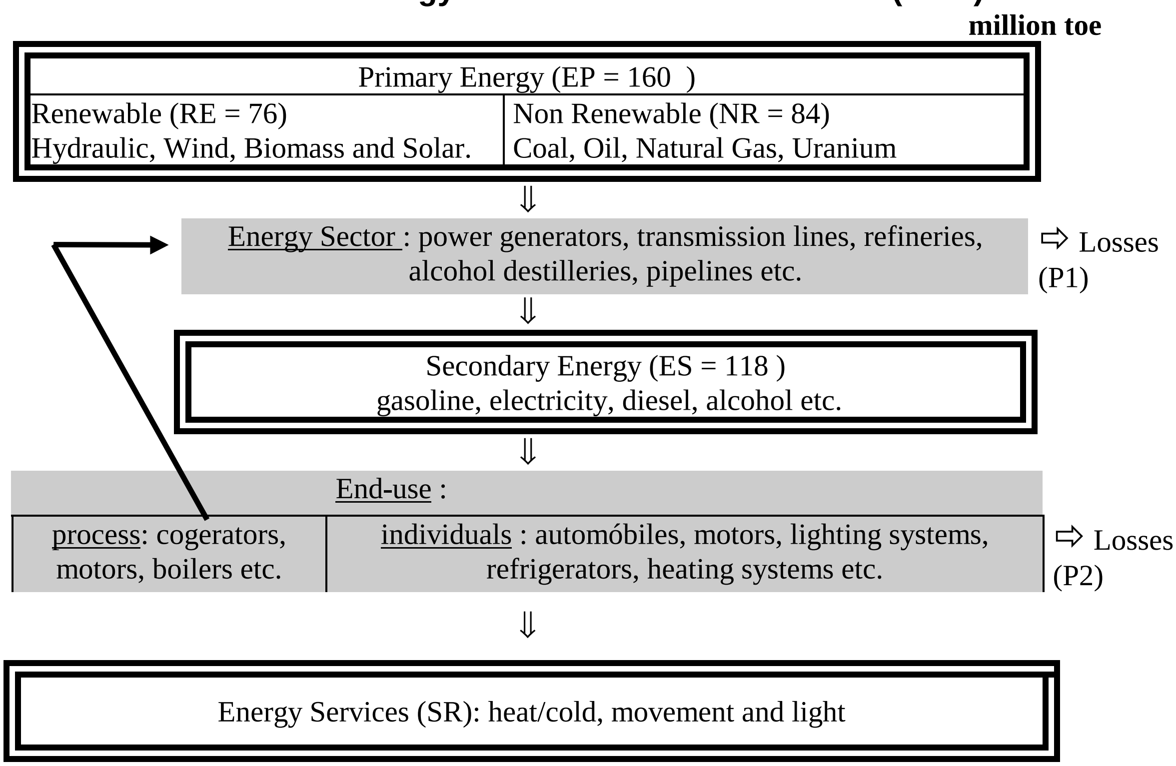
[1] Emissions of other green-house gases caused by the use of energy are not considered (for instance, the methane produced by the organic decomposition of flooded trees in hydroelectrical reservoirs, leaks of natural gas etc). Energy conservation, *ceteris paribus,* will reduce their emission in the same proportion as the reduction of primary energy demand.

2. Energy Emissions - The Current Situation and Trends

2.1 Energy Use, Losses and Efficiency

Figure 2-1 is a schematic presentation of energy`s flow through the economy, from the state in which it is found in nature to its final use. Along these paths, primary energy sources undergo transformations and assume diverse forms. These are measured and can be expressed in a common unit irrespective of the form.[2] The main energy forms are grouped into primary sources, secondary vectors and energy services, each set represented by a framed rectangle. The processes that transform the primary and secondary forms of energy are represented with shaded rectangles.

Figure 2-1
Energy Flows and Transformations (1996)[3]



The energy forms found in nature are called **primary energy** and are divided in: 1) **non renewable** forms, whose use emits CO_2: coal, oil and natural gas[4] and; 2) **renewable** forms, which are directly or indirectly provided by the sun on a continuous basis and whose use does not emit CO_2. They include waterfalls, wind, tides, planted biomass[5] etc.

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[2] In commercial practice, different units are used for different forms of energy (kWh, joule, calories, BTU, etc.). However, it is possible to convert all to one unit. The Brazilian National Energy Balance (BEN) uses the unit "ton of oil equivalent" toe (1 toe = 10.2 Gcal or 45.2 GJ).

[3] Based on the National Energy Balance; BEN 1997. The data were adapted to correct the conversion factors used in the BEN that inflate the relative importance of hydro energy and electricity, and ignore some losses. See amnex A.

[4] Uranium with the current generation of reactors being installed in Brazil cannot be considered "renewable". Among the non renewables uranium that does not emit CO_2., when liberating energy.

[5] When biomass is burnt it emits CO_2 but that is compensated by the fixation of the CO_2 during the phase of growth of the plants, when there is a sutainaable exploration.

Modern economies directly use a relatively small portion of primary energy. In order to be useful, it must usually first be transformed into forms that are easy to transport and stock. They must also be easy to distribute and must be available when and where they are needed. Examples are electricity, alcohol, diesel oil, gasoline etc. These forms are called secondary energy (see the middle framed rectangle).

In this transformation process (top shaded area), part of the original energy is used to attend the energy needs of refineries and distilleries, to transport primary and secondary energy, etc. Thermal power plants also transform into electricity less than half the energy in the fuel, while the rest is transformed into waste heat. This energy, consumed before supplying final energy demand, is considered **losses**. Sometimes losses in this process are not obvious and are difficult to evaluate quantitatively. For instance, about 5% of Brazil`s primary energy in 1996 was stocked in the biomass of the tops and leaves of sugar-cane plantations. With current harvest technology they are burnt in the field.

At the bottom of Figure 2.1 are represented the forms of energy that are used by mankind: heat, cold, light and movement. The secondary energy is used directly by the individuals or indirectly, when they acquire goods and services from factories, commerce and other entities that use energy in their productive processes. These more basic forms of energy are called **energy services** (or "useful energy") [6] and they constitute the real demand of the economy. As it is difficult to measure this useful energy, the demand in practice is evaluated by the secondary energy consumed as if the energy were a proxy.

The bottom shaded area represents the **energy end use system**. It includes equipment such as automobiles, heaters, light bulbs and electric motors which are used by individuals to produce the desired energy service or useful energy. It also includes, the equipment in factories and in the trade and sevices sectors.

The losses of energy in this last phase are very high, sometimes reaching more than 70%, as with incandescent lamps and automobiles. The losses are not exclusively due to the equipment used, but also how it is used. Electric motors, that can have an efficiency greater than 90%, in practice usually work with lower efficiency (sometimes less than 50%) because they are overdimensoned and/or are operated inadequately. Systems of transports also generate great losses of fuels, for example with congestion on roadways.

The drawing highlights the **cogenerator**, a type of equipment that can be used in some processes which produces heat or cold together with electricity. If there is excess electricity produced it can be sold to other companies. Cogeneration is highlighted due to the high efficiency of the technology, it`s great potential and consequently its importance for energy efficiency, as analyzed below.

Energy needs follows the inverse sense of the flow indicated in the drawing. It begins with a demand for services of energy that in turn generates a need for secondary and then primary energy. Choices in this chain will have a major impact on the demand for primary energy. For instance, the need for transportion can be supplied by public or individual transportation modes. In both cases there will be the selection of a vehicle that can be fueled with diesel oil, alcohol, gasoline or electricity. The energy industry - especially the electric power system - can supply the secondary energy demand in several ways. Those choices will heavily influence the proportion of renewables and non-renewables used, and as a consequence the level of CO_2 emissions.

It is obviously impossible to completely eliminate energy losses, but in many cases they can be considerably reduced. The conservation of energy seeks to reduce these avoidable losses without affecting the needs of useful energy and the well being of society. The actions to reduce these losses vary greatly, depending also on whether the reductions are sought in the energy sector (P1) or with final consumers (P2). See Annex A.

[6] The terms are used interchangeably in this report.

2.2 Evolution of End-use Demand and Emissions

End Use

The profile of end use energy demand varies considerably depending on the sector (Table 2-1). The manufacturing sector uses 42% of the total energy and almost half of the electricity. It is also the largest consumer of fuels. The large role of commercial biomass[7] and the reduced use of natural gas are distinctive characteristics of Brazilian industry as compared with that in other countries of similar industrialization. A large share of industrial of energy consumption is concentrates in relatively few subsectors. Some subsectors are especially intensive in the use of energy in relation to their value added.

Table 2-1
Energy End Use in Brazil - 1996

Million Tons of Oil Equival (toe)

	Fuels					Electri-city	Total
Sector	***Oil***	***NG***	***Coal***	***Biomass[a]***	**Total**		
Agriculture	*4.5*	*-*	*-*	*0.0 [a]*	4.5	0.8	**5.3**
Manufacturing	*10.9*	*2.4*	*9.5*	*18.3*	41.1	10.3	**51.4**
Commerce	*0.5*	*0.1*	*-*	*0.2*	0.7	2.8	**3.6**
Public Services	*0.5*	*0.0*	*-*	*0.0*	0.5	2.0	**2.5**
Transportation	*36.3*	*0.0*	*-*	*7.0 [b]*	43.2	0.1	**43.4**
Residential	*6.1*	*0.1*	*-*	*0.4*	6.6	5.5	**12.1**
Final Consumption	*!Erro de sintaxe,)*	*!Erro de sintaxe,)*	*!Erro de sintaxe,)*	*!Erro de sintaxe,)*	!Erro de sintaxe,)	!Erro de sintaxe,)	**118.3**
Non energy	*9.4*	*0.8*	*0.1*	*0.6*	10.9	-	**10.9**
Total	***68.2***	***3.4***	***9.6***	***26.5***	**107.7**	**21.5**	**129.2**

a - Excludes residential and rural/agricultural use of firewood. Source: calculated by the authors based on BEN. See annex A
b - Alcohol for vehicles.

The commercial, public and residential sectors consume relatively very little fuel. The reason for this is the small need for space-heating and the limited availability of natural gas that, in some cases, could compete with electricity. Electric energy use dominates these sectors, supplying 75% of the total energy used in the commercial and public sectors and 46% in the residential.[8]

The transportation sector is the largest direct consumer of fossil fuels, despite the significant use of alcohol from the biomass. Road transport dominates the markets both for cargo and for passengers. The share of transport energy going to road transport increased from 84,6% in 1986 for 90,7% in 1996 - higher than the average of the OCDE or than many emerging economies. The fleet of road vehicles has been growing at a much higher rate than the economy. From 1986 to 1996, the number of vehicles for US$ billion of GDP increased by 52%.

[7] The main biomass fuels are sugar-cane residues, charcoal used in metalurgy and wood residues in pulp & paper mills. Other agro-industrial residues - such as saw-mills and rice hulls - are available but are very seldom used.
[8] This value does not consider the use of the firewood in the residential and rural sectors, which is substantial. The reasons for this are: the very low efficiency of use (that can distort some anlyses), the small contribution to deforestation and the unreliability of the published statistics.

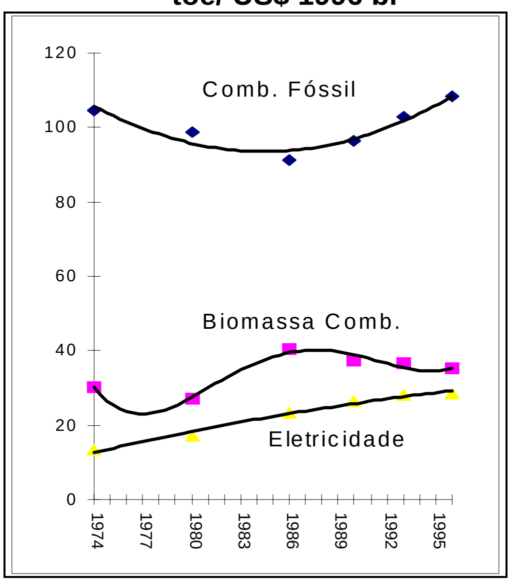
Table 2-2
Evolution of Road Vehicules [9]

	1974	1980	1986	1990	1993	1996
Number of Vehicules (millions)	5.4	10.8	15.0	18.3	22.7	27.5
Average rate of growth (%/year)		*12.4*	*5.7*	*5.2*	*7.6*	*6.7*
Vehicules/GNP (mil/10^9 US\$$19_{1996}$)	14.7	19.8	24.2	28.8	34.5	36.7

Source: National Register of Automotive Vehicules

The intensity of energy use of Brazil`s economy (that is, energy per dollar of GDP) has constantly increased both for fuels and for electricity. Between 1974 and the end of the of the 80’s, this intensifcation of energy use did not increase CO_2 emissions at the same rate. However, in recent years there has been an acceleration in the consumption of fossil fuels. The largest increase was in the transport sector, but it was also significant in manufacturing. From 1993 until 1996 total oil use grew faster than electricity for the first time in decades. During these three years the use of oil grew, in absolute terms, more than in the twelve previous years together. The use of mineral coal and natural gas also grew in this period. These tendencies have been broadly maintained since 1996.

Figure 2-2
Final consumption of Energy / GDP: 1974-1996
toe/ US$ 1996 bi



CO_2 Emissions

Table 2-3 summarizes an estimate[10] of direct CO_2 emissions by the main sectors of the economy as a consequence of energy end use in 1996. Emissions caused by biomass fuels,[11] of non-energy uses of fossil

[9] Values reported in the *Jornal do Brasil*, 12/01/98 edition .
[10] The values are approximate because they use an average coefficient for the emission of secondary fuels derived from oil and coal.
[11] Some biomass uses contribute to defrestation - mainly part of the industrial consumption of firewood and of the production of charcoal. It is difficult to evaluate the proportion of each use that contributes to the emissions over time. This is an important subject and receives some attention later in this paper.

fuels[12] and emissions in the transformation processes[13] are not considered in the table. These simplifications do not distort the results considering the present objective of illustrating orders of magnitude and the relative participation of the several economic sectors in CO_2 emissions.

Table 2- 3
CO_2 Emission of Fossil Fuels
by Economic Sector - Brazil 1996 (10^6 tC of CO_2)

Sector	Emissions	(%)
Agriculture	3.9	6
Industry	21.4	34
Commerce	0.4	01
Public	0.4	01
Transportation	31.2	49
Residential	5.3	8
Consumo Final Energético	**62.7**	**100**

Fonte: INEE. *Balanço de Eficiência Energética do Brasil (*em preparação).

As expected, transportation is, by far, the sector responsible for the largest CO_2 emissions.

International comparisons show that Brazil has a very small contribution for CO_2 energy emissions. As compared with GDP, it is the smallest in the world unlike with what happens with developing countries, where energy intensity in the economies tend to be high. From table 2_4 it is important to remark also the relative importance of transportation sector as compared with other countries.

Table 2- 4
CO_2 Emissions from Fossil Fuels
Brazil and Some Emerging and OECD Countries - 1995[14]

	Brazil	Japan	Europ Union	USA	Mexico	India	China	Russia
CO_2 & economy *($kg\ CO_2/US\$_{90}GDP_{PPP}$)*	0.33	0.46	0.51	0.85	0.51	0.73	0.92	2.24
CO_2 per capita *($t\ CO_2$/hab)*	1.81	9.17	8.55	19.88	3.46	0.86	2.51	10.44
Total CO_2 *(million t CO_2)*	287	1151	3180	5229	328	803	3007	1548
Transport Emissions *(million t CO_2)*	119	252	828	1580	101	112	167	108
Share of Transport *(%)*	41.5	21.9	26.0	30.2	30.8	13.9	5.6	7.0

Source: International Energy Agency, *CO2 Emissions from Fossil Fuel Combustion: 1972-1995*. OECD, Paris, 1997

An analysis of the the evolution of the CO_2 emission intensity of the economy (CO_2 per unit of GDP) over the last decades shows that this coefficient decreased during the 1970s and 80s (see Figure 2-3). The curve

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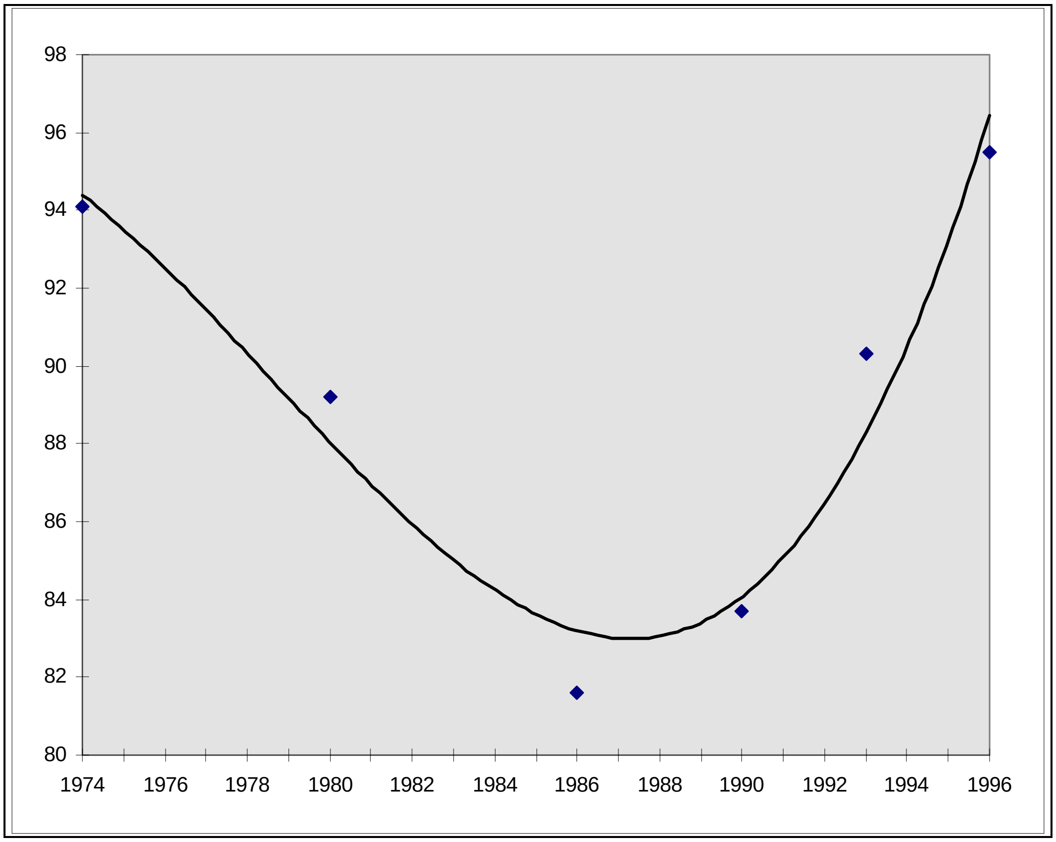
12 How to treat the non energy emissions of fossil fuels is a methodologically complex subject. Different from energy use, the oxidation periods of these materials vary greatly. It can be very long in many cases, such as plastics (that practically are not decomposed). These uses merit specific study, which goes beyond the objectives of this report

13 The emissions in the transformation (in electricity generation, the energy sector`s consumption of fuels, losses in the transformation of primary fuel into secondary forms), which total 10.8 x $10^6$ tC of CO2 were attributed to the consumption sectors in proportion with each one`s share of final consumption.

14 Source: International Energy Agency *CO2 Emissions From Fossil Fuel Consumption 1972/95*.,Paris, 1997. For the comparison among countries PPP is used ("Purchasing Power Parity") instead of the exchange rate of the currency. PPP is used by the IBRD to reflect the effective purchasing power for inputs in the economy of each country.

reached its minimum in the begining of the 90s, thereafter it increases. As can be seen, the inflection is very sharp. On the down-slope, the coefficient decreased at an average of 1 kg C/US$$_{96}$ GDP per year. It has since increased at a yearly rate of 1.4 kg. This change has happened despite the decreasing share of industrial energy consumption since the early 1980s.

Figure 2-3
Emissions of CO_2 from Fossil Fuels per Unit of GDP - Brazil
($tC/10^6$ US$$_{96}$ GDP)



2.3 Evolution of Energy Supply

The declining tendency of emissions observed until the end of the 1980s was due mainly to the increased use of several forms of renewable energy. This growth in renewables was a consequence of a policy addressed at increasing Brazilian energy independence, as the country had few oil reserves and very poor coal reserves on the one hand and rich renewable resources on the other. It is important to observe that although this strategy the reduction of CO_2 emissions as a strategy, the results in this sense were very efective. In some cases these substitutions were made without any attention to efficiency. Also the expansion of capital intensive hydroelectric generation entailed social costs in a country hungry for capital.

Table 2- 5
Primary Energy - Supply Structure in Brazil - 1996

Energy Forms	10^6 toe	(%)
Fossils	**92.6**	**58.2**
Oil	74.8	47.0
NG	5.8	3.6
Coal	12.0	7.6
Biomass	**40.5**	**25.5**
Wood	17.2	10.8
Sugar Cane	23.3	14.7
Hydro(*)	**25.1**	**15.8**
Nuclear	**0.8**	**0.5**
Total	***159***	***100.0***

(*) including 2.9 of the paraguaian half of Itaipu.

For several reasons, the policies that made this substitution possible are at the end of their cycles or in a transition. This explains the change to a tendency of increasing emissions per unit of economic production observed in the 1990s. It is interesting to examine the situation of each of the factors responsible for this change.

Hydro

The main factor responsible for the low level of Brazilian emissions is the mainly hydro origin Brazilian power generation (94% in 1996). The coefficient of power generation emissions in 1996 - 13.6 kgC/MWh [15]- is very low when compared with almost 260 kgC/MWh typical of modern coal power generation stations and 120 kgC/MWh emitted by modern turbines using natural gas.[16] Thus, power generation contributes with just 5% of the total CO_2 energy emissions, much less than the ~30% observed in OECD countries. It is difficult to determine the level of "avoided emissions" because it is not known what would be the Brazilian "mix" of thermal stations if it had not so strenuously developed its hydro potential. As an order of magnitude, if the "mix" were 50% hydro, 25% coal and 25% natural gas combined cycle, the avoided emissions would be on the order of 30 million tC in 1996, more or less 1/3 of the Brazilian emissions in that year.

The option for the large hydro development matured in the late fifties. It was not an obvious choice for a country short of investment capital and at a time when fossil fuel prices were steadily falling. In addition, the large scale of the projects undertaken demanded a strong participation of the Federal government,[17] which led to a growing centralization of decision-making from the decade of 1960 on. The Federal government`s administration also allowed the solution of the complex problem of optimizing the operation of a large number of reservoirs in several river-basins with distinct hydrology. It is estimated that operation without the current optimization would lose about 20% of the hydraulic energy.

In the mid eighties, Brazil`s power sector went through a serious financial crisis and had to severely decrease the rhythm of expansion of generation and interrupt the construction of many power plants - mostly hydro.

[15] The coefficient refers to CO_2 emissions from all fossil fuels used in electricity production, divided by total generation.
[16]"Cogeneration - a leading energy solution to climate change; do International Cogeneration Alliance; 1997; Brussels. Information originally presentede in kg of CO_2
[17] A similar pheneomenon happened in the USA with creation of Federal enterprises such as theTVA and Bonneville Power Adminstration.

In 1993, a process of profound reforms of the power sector began and is still underway. The new institutional model substitutes the government's past central role for a decentralized structure of decision-making based on private initiative. Market forces will from now on define the structure of expansion. The economic base of the utilities has improved considerably, due to the monetary stability and the relatively high electricity rates for captive consumers which were established before privatization.

In the new context, the "Ten Year Power Plan" has lost its traditional role as the official reference for the power sector`s expansion and has become only an indicative study.[18] The last edition, for 1997/2008, reduces the importance of hydro in the short term but emphasizes its role again at the end of the period.[19] However, it does not specify how the large scale investments will be financed, considering the the considerable loss of power of Eletrobrás[20] as a financial agent. Construction at some hydro sites has begun again, but it is very improbable that the share of hydro in the expansion of generation observed in the past will occur again.[21]

Alcohol from Sugarcane

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More than 60% of the sugarcane produced in Brazil is used to produce ethylic alcohol fuel. Of this total, 70% is sold in the hydrated form that completely substitutes gasoline in vehicles and the remaining 30% is sold in an anydrous form that is used as an octane enhancing additive to gasoline (in a proportion of 22% until June 1998, when it was increased to 24%). The production and use of ethanol as the sole fuel or mixed with gasoline reduces current emissions by an estimated 9 million t C.[22]

The substitution strategy was chosen during the oil crises in order to reduce the country`s dependence on oil imports.[23] The Proálcool program was established to increase alcohol supply and assure the adaptation of vehicles to the new fuel. The response was strong. Alcohol production rose from about 0,5 million m^3/year, in the late seventies, to about 13 million m^3/year in ten years, after which it stabilized. This was the only successful large scale program in the world to substitute fossil fuel in transport by renewable energy. In the late 80s, alcohol vehicles accounted for 90% of total sales, even though the threat of rationing no longer existed, and a fleet of 5 million alcohol vehicles circulated in Brazil.

The alcohol program - Proálcool - suffered major problems in 1990, when there was period of alcohol shortages.[24] From this time, considering that the factors that originated the program no longer existed, a

[18] A planning document of this kind is basic for building large hydro plants, due to the indivisibility of the projects,. their long construction time and the guarantee of a market which is necesarry for the financing of such capital-intensive projects.
[19] *Plane Decenal 1997/2008*. GCPS/ELETROBRÁS. May 1998.
[20]Brazilian 1988 Constitution reduced the financial resources and another were removed later by ordinary laws. Thus. it reduced the capacity that had when, for instance, it could finance the construction of the largest civil works of the world - Tucuruí and Itaipu - at the same time.
[21] It is worth noticing in this context that with a twenty year horizon one should consider the possible "disinstallation" for Brazil of half of the capacity of Itaipu (7.000 MW) as the Paraguayan demand for power increases. The Paraguayan utility ANDE projects that demand will reach 2000 MW in 2010 (*Gazeta Mercantil*, issue of 1/6/98, p..23). Considering the low price (25 to 30 US$/MWh) of this energy, it is not impossible that there be an acceleration of this demand. Also, there are Paraguayan treaty rights which could divert power from Brazil.
[22] Macedo, Isaias; "Green House Gas Emissions and Avoided Emissions in the Production and Utilization of Sugarcane & Ethanol in Brazil", MCT Report, 1997. This is a net emission estimate (it considers the emissions resulting from agroindustrial inputs).
[23] At that time Brazil imported about 80% of the oil it consumed.
[24] The alcohol shortage was avoidable. The problem originated with flaws in the planning of the harvest and in the maintenance of tax incentives for alcohol vehicle.

great debate started about its future.[25] Sales of alcohol vehicles dropped sharply and today represent less than 0,5% of new car sales. Even anhydrous alcohol (whose cost is competitive with other octane enhancers) has been threatened with the construction of MTBE factories in Brazil to produce an additive of fossil origin. The new fleet of light vehicule is based on gasoline, and an estimated 300-400 thousand alcohol vehicles are being scrapped each year.

The alcohol program is now going through important changes. The percentage of anhydrous alcohol mixed with gasoline has now been increased by 10%, while the use of alcohol vehicles is obligatory in the Federal government's fleets ("green fleet") and in vehicles sold with tax exemptions (basically taxis). The govenment is studying the possibility of adding hydrated alcohol to diesel oil.[26] These new measures should barely keep the demand for alcohol at today's level. Technological progress that reduces the costs of production of alcohol can be the key for the expansion of this sector, reducing its need for subsidies. The possibility of electricity production in alcohol distilleries is an important option opened by the recent reforms of the power sector which can contribute to a lower production cost for alcohol.

Charcoal

Brazil is one of the few countries in the world that has kept a significant metallurgical industry based on charcoal. This industry produces pig iron and steel of high quality, given the low level of impurities. About 42% of the pig iron produced in Brazil has this origin.[27]

From the point of view of CO_2 emissions, the charcoal industry can have an important impact because it substitutes the use of coking coal as a reducer of iron ore, which emits 0,513 t C/t of pig iron.[28] The current level of use of charcoal avoids an annual emission of more than 3 million t C of CO_2. Actually, the effect is somewhat larger because the planted forests also create a carbon sink.

While charcoal metallurgy is attractive in principle for reducing emissions, in practice it has been a factor in the dynamics of deforestation in the Southeast (Minas and São Paulo States), Center-West and Northern (Carajás) regions.[29] For many years the industry used native wood as the main raw material and there was a rough balance of demand and supply from forest clearing already occuring. The increase in charcoal demand in the eighties exacerbated the predatory aspect of the fuel supply process. This in turn provoked the passage of environmental legislation which inhibited this activity. The average distance of the industry in the Southeast (the largest part) from the sources of charcoal has continuously increased, increasing costs. Consequently there has been a switch to the greater use of raw material from planted forests, as well as a decline in the activity, with some mills closing or substituting coke. Both effects are shown in Table 2-6.

Table 2- 6
Metalurgical Charcoal in Brazil - 1980/96

	1980	1985	1990	1995	1996
Metalurgical charcoal *(10^6 t/year)*	4.9	8.1	8.4	6.8	6.1

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[25] On the one hand there is the subsidy for alcohol and alcohol vehicles, as well as the question of competition with other agricultural products. On the otherhand, besides the low CO_2 emission, it is the form of energy that is most labor-intensive, produces low local pollution, saves imports and he/she has decreasing marginal costs. It also is demonstrating decreasing marginal costs.
[26] Tests in Brazil show excellent results in reducing particulate emissions, a major problem with diesel, with mixtures of 10%.
[27] Horta Nogueira, L. A.; "Bionergias e Sustentabilidade Energética no Brasil"; author`s draft, Itajubá, 1997.
[28] Rezende, M. is et alii, "Commercial Production of Charcoal for Metallurgy", *XXVI Seminário sobre Redução de Minério de Ferro*, Vitória, you are; 29/11/93.
[29] See: P.H. May, A.D. Poole, J.B. Ferraz et alii; op. cit

Share of planted wood *(%)*	-	15	35	55	-

fonte : BEN e Horta(97)

Charcoal metalurgy could grow again, based on planted florests and on technological improvements that increase the energy efficiency at various stages of the process, including the transformation into electricity of some waste streams. For this to be achieved, investments in research are necessary because the programs that once existed with this objective were discontinued. There are positive factors. It is interesting to observe that there have been major gains in the productivity of planted forests in Brazil, while the reforms in the power sector open possibilities for power generation (see chapter 5).

Other Factors

The Nuclear Program

The only operating nuclear power plant in Brazil is Angra I, with 620 MW of installed capacity. Construction began in the late sixties. The objective of its purchase was strategic because at that time nuclear power was seen as the main resource to succeed hydro when the best sites had been developed. The construction proved to be very problematic and operation only began in 1982. Power production has been very irregular and output has been much less than expected (in 1996 it was shut down, but starting from 1997 it has been operating continually).

In the mid seventies, Brazil developed a nuclear program aiming at self-sufficiency (from uranium production and enrichment to manufaturing of plant equipment) that projected the building of 8 plants of 1,200 MW by the middle of the nineties. The program was interrupted and only one plant of 1200 MW (Angra II) saw construction continued. It is expected to be inaugurated in 1999. The completion of a third plant (whose main equipment has already been purchased) is under study. Operating in normal conditions these plants can avoid CO_2 emissions at the margin.

Supply of Isolated Electric Systems

The isolated electric systems are concentrated in the Amazon region, the majority being small units. The total installed capacity in isolated systems in 1996 was 1.8 GW, of which 1.2 GW was thermal, with a total output of 7.1 TWh. The demand growth has been very high - 15% in 1996 and 14,5% in 1997.[30] The service is not reliable and there is a large repressed demand. Although the total size of isolated systems is relatively small, they have a key role in regional development and have the potential of increasing at very high rates. On top of that, in order to reduce the supply costs, there are subsidies[31] to the fuels used in generation. Until recently the structure of the subsidies was such that it impeded the development of local renewable alternatives (such as solar, small hydro and local biomass), that demand higher initial investments. The recent electricity legislation has removed this difficulty. This may mitigate the increase of emissions from isolated systems.

Natural Gas

In Brazil less than 3% of primary energy comes from natural gas, which is very low when compared internationally. This is a consequence of a strategy that determined that the development of demand should be kept as small as possible, since the most important new Brazilian known reserves are located very far

[30] Relatório CCON-CPO-1063/96 ; *Plano de Operações Para 1997*; Dezembro 1996.

[31] CCC and FUPP. The CCC - the "fuel consumpion fund" - collects resources on power sales in other parts of the country and transfers them to Amazon region utilities. FUPP is a subsidy for the transportation of oil derivatives. Its structure is beginning to be reviewed.

from potential consumers. In many countries the use of natural gas is promoted as a way of reducing emissions at the margin. However in Brazil the increased use of natural gas would probably increase emissions, especially if it were used for centralized electric generation substituting hydro.

Starting in 1995, the government has taken a series of steps to increase the availability of natural gas in Brazil. The supply of this fuel will triple by the turn of the century. The effect on emissions can be positive if it substitutes other fossil fuels with higher emissions per unit of energy and if it is used more intensively in cogeneration cycles.

3. Prospects

The picture so far presented suggests that the intensity of emissions per unit of energy used, will grow in the next years. Since there is also a tendency for energy demand to increase more rapidly than the economy, the outlook is for CO_2 emissions to increase substantially - both in relation to GDP and in absolute terms - in a panorama of “business the usual.” At the same time, many opportunities exist to reduce, or even to stop this tendency.

To investigate the impacts of energy conservation on emissions, INEE developed a simple aggregate model to prepare "ballpark" estimates for simplified hypotheses or sets of them. The model analyses possible changes resulting both from factors influencing the growth of end-use demand and from the structure of supply, especially of electricity generation. It is intended as a "reconnaissance" tool. Given the level of uncertainties at this time, including the transition of energy and economic policies, and the diverse possibilities for substitution among primary energy sources, detailed projections of each energy form and of their respective emissions would add relatively little.

Four scenerios were examined, based on the premises summarized below. The first two scenarios are of the type "business as usual", and assume that growth in energy will reflect established and emerging tendencies in the economy. It is important to observe that this is not a mere extrapolation of the past. The consumption elasticities for all the segments are below the values of the last years. Therefore, as high sceneries they are relatively conservative - with the same economic growth assumed (4,5%/yr in all the scenarios) the emissions could be larger.

I	**No conservation with high natural gas penetration.**	End-use energy follows trends. The supply of new power generation would be strongly based on the use of NG in central power stations (~50% of total expansion is thermal and 43% is gas in central stations)
II	**No conservation with less natural gas use.**	Same as above with a smaller penetration of thermal power generation in general and of NG (~37% of total expansion is thermal, 31% is gas in central stations)
III	**Moderate conservation - in industry**	Iindustrial demand is 10% lower in 2010 compared with businees as usual. Also assumes that an important part of new generation comes from cogeneration (16% of total)
IV	**Moderate conservation - includes transport**	Same as above but expands to include moderate conservation actions in the transportantions sector

The key difference between the two high sceneries is the share of natural gas in the expansion of electricity generation between 1996 and 2010. Scenario I supposes a strong penetration of natural gas: 44,5% of total expansion would be with the natural gas (almost all in central stations), another 5,5% would be from other fossil fuels. Scenario II foresees a smaller participation of gas (32%), even so this is still substantially above the share projected in the *Ten Year Plan: 1998-2007*. However, both scenarios are compatible with expectations of experts in diverse sectors regarding the expansion of natural gas given its characteristics of speed and modularity in response to demand.

Scenario I`s total for natural gas are consistent with projected volumes of imports and domestic production on a ten year horizon. In both these sceneries, the coefficient of CO_2/GDP continues to grow at a rate greater them obsrved in the the last years. See Table 3.1.

In the two scenarios with "moderate" conservation, we illustrate the impact of a reduction of 10% in industrial energy use in 2010 (Scenario III) and then consider a similar reduction in transport (Scenario IV). In both these scenarios one can see also the effect of reallocating 1/3 of the natural gas used in Scenario II for central power stations to cogeneration.

Table 3-1
CO_2 Emissions in Brazil: History and Scenarios
(Million t of C)

	HISTORICAL						Scenarios-2010			
	1974	**1980**	**1986**	**1990**	**1993**	**1996**	**I**	**II**	**III**	**IV**
Natural Gas	0,49	0,79	2,27	2,72	3,05	4,01	26,72	22,77	19,37	19,26
Oil	32,1	42,6	39,0	41,5	45,9	56,2	127,7	127,7	121,2	112,0
Coal	2,86	6,32	10,8	10,4	12,0	13,3	26,5	25,9	19,1	19,1
Total	**35,44**	**49,66**	**52,11**	**54,60**	**61,0**	**73,5**	**181,9**	**176,4**	**159,7**	**150,3**
GDP *($US\$_{96}$)*	367	546	621	635	659	749	1387	1387	1387	1387
Intensity *(kg C/US$)*	96,6	91,0	83,9	86,0	92,6	98,1	130,4	127,2	115,2	108,4
Average growth *(kgC/yr)*	-	-0,94	-1,17	0,51	2,20	1,85	2,31	2,08	1,22	0,73

Note Historical data and scenarios by: A.D. Poole and J.B. de Hollanda, *Scenarios of Emissions of CO_2 from Fossil Fuels in Brazil*. This publication by INEE will soon to be available.

Conservation measures assumed for the last two scenarios are relatively modest and feasible. Nevertheless, they represent an important effort. For example, the reduction in the final consumption of electricity is equivalent (a little larger) to the long range goals of PROCEL. The impacts on emissions are substantial. As shown in table 3.1, there is a reduction of 28% in the growth of emissions in the Scenario IV in relation to the Scenario I, and of 25% in relation to Scenario II.

However, the coefficient CO_2/ GDP continues to increase. To revert this tendency, or to stabilize at the 1996 emission coefficent, deeper interventions would be needed, especially in the transportation sector. While potentials exist - considering the possibilities detailed in Chapter 5 - it is important to recognize that their realization will depend on clear political will backed up with effective strategies. That leads us to the subject of the next chapter.

4. Making Energy Efficiency & Emissions Reduction Happen

Normal technological progress usually increases the efficiency of equipment. This phenomenon has been accelerating over the last decade with the trend toward growing automation, where "information substitutes energy". [32] The reasons for increasing energy efficiency faster than would occur with this "natural tendency". can be of several origins.[33]

The economic motivation for an individual or an enterprise is a consequence of a comparison between the cost of reducing energy losses and the savings obtained from the decrease in energy bills.

In macrecronomic terms, the motivation is basically the same. However, it is much more difficult to characterize and evaluate all the costs involved, which include imponderable factors such as atmospheric pollution, capital and labor intensiviness. An example of the difficulties is the definition of the costs associated with CO_2 emissions. Since the greenhouse effect is global (the emission in any country affect the whole world and avoided emissions anywhere also benefit the whole world), how do we evaluate the "cost of heating of the earth" ? In case there is consensus with relation to a formula, how to apply it? In the specific case of Brazil, that already has among the smallest emissions in the world, how to reward it for the effort?

4.1 "Laissez Faire" vs Conservation

For many authors, energy efficiency would be a natural consequence of the action of market forces, provided that an appropriate structure of energy prices exists. The report of Coopers & Lybrand on the new model for the electrical sector, when analyzing the theme, summarizes this position well:

> "(c) the definition of the generation prices by the market, implicit in our proposals, will provide strong incentives for consumers to invest in energy efficiency as a way to reduce demand.
> ......
> (f) the structure of price controls of the proposal as a whole will minimize the disincentives to the development of the energy efficiency." [34]

From this point of view, there is no need for a conservation "policy" (understood as a government intervention), because the market would take charge of guiding consumption in an optimal way. In practice, all the industrialized countries[35] have energy efficiency policies. They understand that many barriers impede the market from behaving in an ideal way (see Annex C) and that to have energy prices reflecting production costs is a necessary, but not suficient, condition to guarantee the optimal use of

[32] There are diverse examples, such as process computers that otimize the use of energy in factories and appliances. The tendency is partly obscured by the demand for ever more powerful equipment (e.g. cars with more horsepower to accelerate faster; bigger vacuum cleaners, etc.) to See: Xinhua Chen; "Substitution of Energy for Information in System of Production" in *Cadernos de Eficiência Energética*, INEE; October 1993; p. 19.

[33] See: *Energy Efficiency and Conservation - Strategic Pathways to Energy Efficiency in Brazil*, INEE/ ESMAP, Rio de Janeiro, 1995; p. 3.

[34] See item 84 in: *Project for Restructuring the Brazilian Electrical Sector, Stage VII*, Ministry of Mines and Energy, 1998.

[35] Even and above all in the USA, whose liberal market principles are not in dispute and where many price signals have been relatively free.

energy. [36] It is assumed here that a "conservation policy" is desirable due to the intrinsic merits of its economic and environmental impacts.

Market imperfections can be addressed through different instruments: economic, information, and command and control. Economic instruments include actions such as: specific credit lines, guarantees, tax incentives, the structure of energy prices and cross subsidies, and support for research. Information actions range from publicity, labelling and awards, to data bases, teaching and the certification of some professionals. Command and control actions include norms and regulations, such as those requiring minimum efficiency standards for equipment.

There are, evidently, important differences in the degree of the government's intervention. A subsidised credit line is an example of a highly interventionist action. On the otherhand, measures to assure the functionality of performance contracting in the market, or requiring engineering schools to include courses about energy management in their curricula, interfere much less and can have important long term effects.

As discussed further in section 5.2, these actions are most applied to energy end uses where conservation depends on actions taken by millions of agents, having very heterogeneous levels of information. The key word is seeking "market transformation" so that it will work better. The goal of transforming the market to achieve more efficiency is now reinforced by the greater realism of energy prices (in spite of the existence of some distortions[37]) and by low inflation resulting from the monetary reform. This price stability is a prerequisite to developing an economically viable market oriented policy for increasing efficiency.

4.2 Government Imperfections

Some signals leading to energy losses are the consequences of policies that, aiming at a specific objective, end up motivating energy inefficiency. The most important example in the recent past was the policy to keep many government-controlled energy prices below the costs of production, as a means of reducing the published inflation indexes. At present, the high interest rates designed to attract international investments reduce the relative attractiveness of the many conservation measures that require up-front investments. The high valuation of the Real compared with other currencies also reduces the competitiveness of domestic renewable fuels with imported fossil fuels.

A major part of the distortions are a consequence of the centralized structure of the power sector that was so important for the development the country`s hydro potential, as mentioned earlier. This hegemonic structure, for example, impeded the obvious and cost-effective development of power facilities to use energy wastes at steel mills and the sugarcaneagroindustry. [38]

The new model for the electric sector being implemented in Brazil, creates competition in power generation, reduces protectionism for the utilities and creates new agents and mechanisms for competition. These novelties should increase the energy efficiency in the transformation of primary energy. They may also stimulate supply solutions based on the use of renewable energy forms. On the other hand, the privatization of the power sector, together with the deverticalization of the utilities, may jeopardize some actions to

[36] In the Coopers & Lybrands document cited above which declares that price signals are a necessary and sufficient condition, it is proposed that PROCEL (the electricity conservation coordinating agency) be maintained and that a component of the electricity price be formulated and applied in conservation.
[37] For example, the prices of peak hour electricity are so high that, in mid-1998, it is attractive to operate the emergency diesel generators on aregular peak hour basis.
[38] This kind of distortion is not a uniquely Brazilian problem. In Sweden, in the sixties, cogeration development with district heating was obstructeded so that it would not reduce the market for nuclear power development. Cogeneration in the USA, England and France only developed when competition was allowed to develop in power generation..

promote more efficient electricity end-use by consumers. In the new model, the role of energy regulation has grown greatly in importance and will be of the utmost importance to avoid or reduce distortions such as those observed in the past.

4.3 Brazil`s Approach

In the developed countries, the incentive to the increase of the energy efficiency is often linked to the objective of reducing the emissions of CO_2. [39] As shown previously, in spite of not being historically motivated by the issue of reducing CO_2 emissions, some of the priorities of Brazilian energy policy have had the result of mitigating their growth. In the first years after the first oil price shock of petroleum, there was a strong emphasis in the substitution of imports of petroleum, motivated by concerns of security of national supply.

In this period, efficiency in the end use of energy was not emphasized. This picture began to change from the mid eighties - which was also a period characterized by the loss of momentum of the renewable fuels substitution programs. At the end of 1985 PROCEL was created to stimulate the efficient use of electricity. In 1991 CONPET was established with similar objectives aimed at oil derivative and natural gas. Both programs are articulated to the National Department of Energy Development of the Ministry of Mines and Energy, but they are administered by Eletrobrás (in the case of PROCEL) and Petrobras (CONPET). [40] The main motivation for creating these programs was to reduce the investment requirements of these two companies controlled by the government.

The strategic plan for the electric sector (known as the “Plan 2015”) has set a long term goal for PROCEL to reduce the consumption of electricity by 75 TWh in the year 2015, through conservation actions. That is equivalent to a reduction of 11% in the consumption projected for that year if no conservation measures were taken. Through 1997,[41] PROCEL had invested R$ 76 million,[42] causing an estimated accumulated economy of 5,6 TWh (1,8 of which in 1997), thus avoiding investments in power supply estimated to be R$ 2,6 billion. In this effort, a great range of activities is being developed - from TV publicity to incentive programs for appliance manufacturers to improve the efficiency of their products. The funds for PROCEL basically originate in the operations of Eletrobrás.[43] That resource has been reinforced with the support to PROCEL from international agencies and it is working to obtain an important loan from World Bank. The privatized distribution utilities also have a commitment to invest about 1% of their revenues in projects to increase the efficiency of electricity use.[44]

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[39] This happens in several ways: 1) association of efficiency gains with the reduction of the environmental risk of the greenhouse effect, better understood by the population; 2) subsidies or tax incentives for the use of renewable resources; 3) taxes to increase the cost of fossil fuels (“carbon tax”), which can also motivate the increase of efficiency; and 4) mechanisms in study by which those who emit CO_2 below a certain level, can sell an “emission right” (or “emission bonds”) for who exceed the limit.

[40] A summary of the evolution of energy efficiency policies until 1994 is found in: A.D. Poole, J.B. de Hollanda & M.T. Tolmasquim, *Energy Efficiency and Conservation: Strategic Pathways for Energy Efficiency in Brazil*, INEE for World Bank/ESMAP, 1995.

[41] In the period 1990-93, the PROCEL program was almost discontinued. Since then it has grown substantially.

[42] In PROCEL’s budget, about 2/3 are destined to reduce energy losses within the utilities. Thus, the investments to improve end use eficiency were of the order of R$ 25 million. (Report of the *Meeting of the Group of Support to the Executive Secretary of PROCEL/Eletrobrás*, PROCEL, May of 1998).

[43] Besides the operational resources of the company, the application of part of the resources of the Federal fund - RGR, administered by Eletrobrás - is foreseen until the year 2003 in projects to reduce electricity losses in municipal governments.

[44] This is equivalent to about US$ 200 million per year today. Of this total, at least ¼ should be destined for end-use conservation projects.

The goal of CONPET is to reduce the consumption of oil derivatives and natural gas by 25% in 20 years, by increasing the efficiency of their use. CONPET's work have emphased the economy of diesel and LPG, which both face limits in Petrobras' refining structure. Some concrete results have been achieved in the transportation sector, as well as in a labeling project for stoves which provides efficiency information as guidance for the consumers. Part of CONPET's activities are directed towards reducing energy consumption within Petrobras' industrial and commercial facilities. Among other projects is the development of 2GW of cogeneration facilities in the industrial units of the company (see section 5.2).

The investments by these agencies are relatively small considering the dimension of the problem. The future of the programs presents uncertainties due to the process of privatization and the institutional and regulatory restructuring of the energy sector. For instance, what will be the future of CONPET and PROCEL if Eletrobrás and Petrobras were privatized? Will the logic of the new energy model drive the gas and electric utilities towards a more or a less favorable posture towards improving efficiency among their costumers? How may the kinds of activity change?

4.4 External Issues

Energy efficiency and the reduction of CO_2 emissions have some particular characteristics that make them sensitive to external factors which are worthwhile considering.

Thus, policies directed to these themes in the richer countries, which are large emittors and where there is political pressure to act on the problem, [45] can have the opposite effect for countries such as Brazil - reducing or even nullifying the objectives sought. For example, the taxation of fossil fuels ("carbon tax") in the large emitting countries, if it induces their economies to reduce consumption or to switch to renewable alternatives, can decrease world demand for fossil fuels and consequently decrease prices (which already are low due to the global economic situation). It can also lead some high emission indiustries (steel plants, for example) to transfer their operations to other countries where there are no taxes.

In this situation, Brazil faces the risk of: 1) accelerating the abandonment of renewable energy sources, accentuating the tendency observed in Figure 2-1; and 2) being stimulated to use fuels more inefficiently, notably in the transport sector where the wastes and the emissions are already the highest in the country.

This problem with carbon taxation can be overcome or mitigated if mechanisms were established for international financial transfers specifically seeking to reduce the emissions (eg "emission bonds"). Considering Brazil`s capacity to respond in this area, as has been demonstrated in the past and that the country has a great potential to reduce emissions, financial incentives can create an extra impetus to increase energy efficiency.

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[45] In the USA, despite the resistance to action of industries and of the Congress, a *New York Times* poll (cited in *O Globo*, 29/XI/97, p.43 reveals that 65% of the population wants the country to reduce grenhouse gas emissions.

5. Where to Increase Efficiency?

As shown in Figure 2.1 earlier, the losses observed in the end-use of energy are of a very different nature than those observed in the process of transforming primary energy into secondary forms. The transformation of primary energy is done by a small number of enterprises, among them some of Brazil`s largest companies, with annual revenues on the order of US$ 40 billion and assets that exceed US$ 200 billion. These actors are more responsive to the market signals for efficiency because they can transform into income the reduction of the losses of energy under their control. However, given the gigantic size of these institutions (many state-owned monopolies to this day) they also tend to obstruct market developments that threaten their activities and this power is sometimes used to hinder efficient actions by end-usrs.[46]

In contrast, the end-use of energy occurs in millions of units, with a total stock of investment that may exceed US$ 300 billion. These consumers are more exposed to the market imperfections previously commented (Annex C) and to increase energy effciency in this segment some kind of regulation, taxes or other intervention are normally required.

In what follows the possibilities of reducing energy losses are analyzed for each of these main families of actors. As both segments are increasingly exposed and influenced by international forces, the analyses also consider this aspect.

5.1. Reduction of Losses in the Transformation Process

In the traditional model of the power sector, electricity generation was considred a monopoly of the enterprises constituted with this objective. This attitude towards the business inhibited the development of important available resources that could be transformed into electricity, thus contributing to the waste of large blocks of energy .

Following a recent international trend, the new model of the Brazilian power sector aims at creating the necessary conditions to stimulate competition in power generation through: the creation of Independent Power Producers (IPPs), opening access to the grid, the regulation of power brokers for commercializing energy and the creation of a Wholesaler of Electricity Market (MAE). These new facts have created more propitious conditions to develop power generation using resources that today are wasted. The development of these potentials close to the load centers will also reduce electrical transmission losses.

Table 5.1 gives an idea of the range of potential growth of generation from these resources, based on considerations presented below. Their relative importance can be judged when one notes that in 1997 electricity consumption was 280 TWh.

Before analyzing the main possibilities, it is important to observe that the relationship between conservation actions and the reduction of CO_2 emissions of this tranformation segment in Brazil is not always direct. This is because an important part of the primary energy for electricity generation is of renewable origin.

[46] This is not just a Brazilian problem. In England, where the deverticalization of power utilites is considred a key characteristic of the new model because it strengthens competition, bulk suppliers have made several attempts to take over distribution utilities.

Table 5-1
Potential of Loss Reductions in the Electric Transformation
(TWh/year)

Cogeneation - large units	15 - 20
- small units	4 - 8
Power Sector	30 - 40
Oil Sector	15 - 20
Sugarcane	20 - 60
Iron & Steel - Coke	10 - 15
Iron & Steel - Charcoal	4 - 6
TOTAL	98 - 169

Cogeration with Natural Gas

Cogeneration can use any kind of fuel, but the technologies using natural gas have developed furthest in recent years, reducing production costs even for smaller power plants. With the increase of natural gas supply, Brazil can use the latest generations of technologies. The development of this potential can thus be very fast, as happened in France for example.[47] The permitting and construction times for smaller scale plants especially can be quite short, as already observed in Brazil,[48] which can facilitate rapid penetration in the market.

The advantage of this technology is the high conversion efficiency into useful energy: up to 85% (or more in special cases) of the energy in the natural gas. The "disadvantage" is that the heat cannot be transported over long distances, which means that cogeration must operate close to industries and commercial establishments. Depending on the relative needs of heat and electricity, the cogenerator may produce electricity surpluses and sell them to the grid. In the Brazilian system, the cogenerator should play an important part in regularization of the power system if appropriate price signals exist: he can either sell electricity to the grid or transform himself into a load (for example, if there is excess hydroelectricity being offered at a sufficiently low price, he may turn off the cogeneration and buy electricity from the grid both to supply normal needs and even to produce steam with an electric boiler).

The studies of potentials are few, but an interesting indicator is that in countries where there is no restrictions on the natural gas supplies, cogeneration represents from 10 to 15% of the installed capacity[49]. The estimates in Table 5-1 are conservative. In Chapter 3 an analysis of this sceneries shows effects in emission of the two possibilities.

[47] In France, eliminating some market barriers increased the orders for cogeneration capacity from 40 MW in 1993 to almost 600 MW in 1997 and more than 1000 MW expected in 1998. Folder of the Club Cogénération, January 1998.
[48] In the Kaiser beer breweries an IPP made the project proposal, obtained all the necessary licenses and financing and installed a unit of 20 MW in an 8 month period. See the *Proceedings of the International Seminar on Cogeneration & Distributed Generation*, INEE, Rio de Janeiro, May 14-15, 1998; available in CD-ROM.
[49] It could reach 30% of total generation in Europe; see Electric Power International; "Special Report :CHP : choice of the next generation ?"; Summer, 1998; page 25;.

Oil Sector

Brazil`s existing refineries are relativelly old and were designed before the oil crises, when little attention was given to energy efficiency. Petrobras, stimulated by the power sector`s new model, is associating with IPPs to develop the cogeneration potentials in these units, which amount to about 2,5 GW.[50] It is legitimate to imagine that other eficientization actions in these refineries and in the oil transportation system could even more impressive results.

Sugarcane Sector

Although sugarcane represents the equivalent to 23 million toe of primary energy, the derived alcohol supplies only 7 million toe to final use. The historical reason for this low transformation efficiency is that PROÁLCOOL sought exclusively to substitute gasoline, instead of the integral development of the energy potential of sugarcane. The distilleries were inhibited from generating power, a logical step since the alcohol represents only 1/3 of the total energy chemical energy stored in the sugarcane. The remaining 2/3 are stored in biomass that, with existing technologies, could produce about 20 TWh/year. This production could triple, turning power generation into the main activity of the sugarcane industry. A technology for this purpose is being developed in the Northeast of Brazil with the support of the IBRD and the GEF.

From the point of view of reducing emissions, the most important contribution of the development of this potential would be to contribute to the long term economic sustainabilility of the alcohol program.

Coke Steel Mills

The potential for cogeneration in the main Brazilian steel mills is large, as shown in Table 5.1. For example, the largest mill - CSN (Companhia Siderúrgica Nacional) - buys most of its electricity needs from the grid, about 3 TWh/year. Similar size mills in Japan today export power, taking advantage of the several energy forms available in the process of iron reduction - such as gases from coke ovens and blast furnaces (including even the kinetic energy in the blast furnace gas). Many mills are already planing to develop their cogeneration potentials.

Charcoal Metalurgy

The technology used in most plants for pig iron production is relatively primitive. The energy in the charcoal consumed per ton of pig iron is substantially higher than in the coke steel mills. A 30% reduction or more in the charcoal consumption per ton of pig iron is feasible. At the same time, electricity can be generated. The energy efficiency of the transformation of the firewood into charcoal can also be substantially increased.

The survival of this sector requires productivity increases along these lines, together with investments in renewable sources of wood, such as reforestation and forest management. There is evidence that this strategy is economically feasible, at least in some areas. However, there are few intiatives to implement this transition towards a sustainable basis. This sector does not have an R&D center to develop relevant technologies (as Copersucar does for sugarcane), while some companies that once exercised a role of technological leadership no longer invest in this development. Many pig iron plants in Minas Gerais are being converted to operate with coke, either substituting charcoal integrally or with a large percentage of coke.

[50] *Ten Year Expansion Plan for the Power Sector: 1998/2007*; GCPS; Eletrobrás; May 1998, p. 78.

Power Sector

The losses in the power sector`s transmission and distribution systems have "disinstalled" the equivalent of 0,5% of the existing generating capacity per year (about 300 MW in 1997).

Table 5-2
Transmissão & Distribution Losses in Brazi`s Power Sector: 1990-96

Year	90	91	92	93	94	95	96
Losses *(%)*	13,0	13,8	13,6	16,6	15,5	15,7	15,7

Considering the levels of power losses already observed in Brazil in the past, as well as the fact that the losses experienced in other countries are between 8% (France, USA) and 10% (Spain, Norway), it is expected that measures in this area can yield 4 - 6 GW. This reduction can happen naturally with the decentralization of power generation and as the utilities become more conscious that investments to reduce these losses have high economic returns.

The increase in thermal generation capacity operating in a model with better market signals will allow also a better modulation of loads and the use of the "secondary hydraulic" energy that today is lost over the spillways. This energy, which is essentially zero cost, amounts to about 3 to 5% of hydro generation. [51]

Other important possibilities for reducing losses in hydrelectric generation include the repotencialization of old plants and reducing the time needed to clean the cooling systems. The latter measure, in the Balbina plant, increased electricity output by 5%.[52]

5.2. Increasing End Use Efficiency

The discussion of end-use is divided by sectors of consumption. We make observations on tendencies, savings potentials and barriers to greater efficiency. We also considered the demand for energy services, where policies which indirectly influence energy use and efficiency are important, as for example in transport infrastructure or the recycling of energy intensive materials.

Transportation

Transportation is the sector which contributes most to emissions of CO_2 and which has the largest consumption of fossil fuels (the share of electricity is insignificant). It is the sector whose emissions have grown fastest in recent years. At the same time, there big structural and technological changes occurring in the sector, which should accelerate - both worldwide and in Brazil. Due to the very large number and diversity of the agents involved, it is a very complex sector for a policy to promote energy efficiency. Yet it is the sector which is least studied in Brazil and probably in the world.

The transport sector is composed of subsector/markets with very different characteristics and dynamics. The differences among, say, the market for individual cars and aviation or bulk freight are almost as big as

[51] This value is not published. It is based on the "educated guesses" of specialists for years in which reservoirs levels are such that supply is not at risk.
[52] Cleaning is usually down mechanically, which requires a long downtime. The new proceedure developed for Balbina, with the support of PROCEL, uses chemicals and shortens time substantially.

the differences between the markets for energy consumption in residences and industries. There are several approaches to classifying these markets. One is the distinction between passenger and freight, another is between urban/local and interurban/long distance transport. Within these four broad categories there is competition among transport modes. For example, in the case of urban passenger transport there are the options of individual cars, buses, taxis, "paratransit" and sometimes train, metro or ferry boats.

Unfortunately, the studies available do not allow an accurate division of energy of energy use among the different categories. However, there are two areas which are clearly of great importance: (1) road haulage of freight and their insertion in the intercity transport of goods; (2) the individual car and its insertion in urban transport.

There are three basic factors that affect the energy consumption of a transport market category.

1. *the demand for transport service* - defined as, for example, ton-kilometer or passenger-kilometer.
2. *the transport mode used* - among the possible modalities there can be a large difference in the average energy consumption per unit of service. A complication is that the transport services provided by each mode are not necessarily exactly the same.
3. *the efficiency of the transport mode* - the average efficiency of the vehicles of the modality. This is a result of the technology of the vehicles and the conditions of their operation.

In Brazil, as in the world, most emphasis has been on the last factor - the efficiency of the modality and particularly the efficiency of the vehicles of each modality (especially road vehicles). In fact, there are technological advances happening that promise very large gains in vehicle efficiency on a ten year horizon. An important example is the arrival of a new generation of motors and propulsion systems that will allow automobiles to double *or triple* there present efficiency. [53]

The first two factors mentioned above (service demand and the choice of transport mode) can be seen mainly as targets for "indirect" measures to improve energy efficiency. They involve choices and priorities for several kinds infrastructure that would represent a change in the direction over the last decades. Therefore, they are politically even more complex than the initiatives to increase the efficiency of vehicles.

In spite of the complexity, to influence the demand for transport services and the profile of the modes used will be important factors in the great adjustment required over next decades. A recent study[54] shows that differences in historic policies and geography have resulted in very different service demand levels and modal shares and efficiencies modal among regions of industrialized countries with similar per capita income. For example, the per capita energy consumption for individual terrestrial transport in North America is 2,5 times that in Europa Ocidental. The impacts of these interrelated factors will demand a broad political vision; otherwise a good part of the energy and environmental benefits resulting from the advances in vehicle technology will be nullified.

The background for public policies will be marked by several factors that can alter historical tendencies - "trend-breakers" - such as:

- *environment* - concern motivated mainly by local sound and atmospheric pollution;
- *lifestyle* - organization of work and telecommuting; type of vehicles desired (larger or for leisuree or even for safety in accidents)

[53] An important example is variants of the hybrid vehicle concept: a generator operating in an optimized regime charges batteries which power the electric motors for traction. There are prototypes using fuel cells, microturbines, Wankel engines, as well as conventional cycles and other prime movers. They can become commercial over the next decade. President Clinton attributes this technology as being one of the main factors for reduction of US emissions.

[54] World Energy Council, *Global Transport Sector Energy Demand towards 2020*, London,1995.

- *new technologies* - beside the new generation of cars, and perhaps as revolutionary, a group of technologies is appearing for automatically charging for the use of road space - "road pricing." The impetus comes from the increasingly problem severe of congestion. [55]

These new tendencies will have consequences for all the factors that determine the consumption of energy in transportation. At the same time, energy (and emissions of CO_2) will rarely be the decisive criterion in the choice of alternatives. It is necessary to link the energy benefits to other themes. Possible linkages are not lacking, due to the large externalities associated with transportation.

In Brazil, the efficiency of vehicles increasingly reflects international tendencies. This is in good due to the relative opening of the domestic automobile industry and to the "world car" strategy of the manufacturers. Until the beginning of the 1990s the market was practically reserved for domestic manufacturers and there was a technological lag in many areas. For example, medium-sized trucks with designs essentially of the 1950s continued to be produced in great numbers until recently. The historic lag means that there should be opportunities as the vehicle fleet is renovated.

Fuel pricing policy for individual cars - gasoline and alcohol - resembles that in European countries, with relatively high taxes. This is an incentive to purchase more efficient vehicles. However, the effect on purchase decisions seems modest, at least in the current range of fuel prices. For other types of vehicles the price of the fuel (mainly diesel) is either subsidized explicitly or is taxed at levels well below the externalities of their consumption (including cost of maintenance of the highways).

The objective should be the constant incoporation of the advances occurring in vehicle efficiency and safety into those that produced in the country and imported. The growing international trade in vehicles and components should generaly encourage development in this sense. However, a certain care is warranted. For example, some imported models (as notably the Lada) were of notably low quality. There is a justification for norms on energy performance, which also be reflected in the differentiation of taxes incident on vehicles.

Another set of issues concerns the mitigation of the growth of demand for transport services and particularly of the energy-intensive modalities. In Curitiba there was a demostration of the possibilities, mainly in relation to the individual car and urban public transport. Energy wasn`t a primary motive for the measures taken (congestion and local pollution were more important). Nevertheless, they resulted in a clear reduction (~25%) of consumption of fuel for car in relation to other cities of similar size.[56] In spite of the success of Curitiba`s program and its political popularity, there were little adaptation and application in another Brazilian cities. It shows the difficulty of the implementation of "indirect actions" involving infrastructure.

New pressures should with time force a "new look" onto the expansion of Brazilian infrastructure, with consequences for energy and emissions of CO_2. The congestion in cities and the high costs of transport of "commodities" in many regions are two examples. At this time it is important to, at the very least, restart essential analytic work on the subject. Such work has been abandoned in Brazil since the mid-eighties.

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[55] Automobu\ille trips typically require 10-50 times more roadspace per passenger than other modalities. In addition, the increasing motorization of individual transport creates a new pattern of occupation of urban space that generates more trips with longer average distance. All this increases traffic congestion. See A.D. Poole, R. Pacheco and M.A. Campelo of Melo; *Moving People: Transport Policy in the Cities of Brazil*, International Development Research Centers, Ottawa, 1994.

[56] The measures taken in Curitiba include: planning of the urban space; priority for buses in the road space and other actions to increase their average trip speed; integration of the system - both physically and for bus fares.

Industry

Industry is the second largest source of emissions and the second largest sector for the final consumption of fossil fuels.[57] It is also, by far, the largest sector of electricity consumption. With the increasing weight of electricity generation in emissions, the industrial sector will probably become the largest contributor to CO_2 emissions in the medium term. The sector is characterized by the great diversity of processes used. At the same time, a large part of industrial consumption is concentrated in a few sectors.[58]

There is a lack of systematic studies of the potential savings in industry. Examples of recent projects suggest that, in most companies, savings of the order of 15% in end-use are conservatively feasible in the short term - excluding the gains from cogeneration. Technological evolution, led by informatics, opens the prospect of larger reductions of consumption in the medium and longer term.

In proportional terms the larger economies are probably to be found among medium and small consumers. These also face much higher unit costs of energy than do large consumers.

In general, the level of awareness in industry is still low. In most companies energy is only a small share (less than 5%) of total costs, and it is generally treated as a fixed cost. The monitoring of energy use is often minimal. Even large consumers often do not know the real cost of, say, the steam that they use.

One road to increasing the awareness and mobilization of businesses will pass via the objectives of increasing their overall productivity and improving the quality of their products. The opening of the economy to stronger competition (both domestic and international) is pressuring business in this direction. The wide diffusion of the ISO 9000 and 14000 is a general manifestation of this motivation at the international level.

Another mobilizing factor will be the entry of natural gas and accompanied by the emergence of cogeneration as a practical option. When companies prepare to change their fuel it will be an opportunity to stimulate interest in wider energy otimization, especially when they evaluate cogeration projects.

Seen in this context, the "selling" of the idea of energy otimization and its benefits should be holistic. It should include all forms of energy, as well as other "utilities" in factories such as water, compressed air and gases which are often important energy vectors. Frequently it will be important to link energy savings to specific improvements of productivity, quality and control of environmental emissions. Unfortunately, today the "selling" of the concept is somewhat fragmented, beginning with the institutional segmentation between energy forms.

The implementation of projects today faces difficulties with third party financing and in the risks and costs of the transactions involved. Third party private financing of projects is still new in Brazil. For projects aimed at end-use there are additional difficulties, as their scale is relatively small and there is a lack of familiarity.

The subject is distant from the core activities of the great majority of consumers, while the supply of diverse services is incipient and little structured. Suppliers of project services still need to build capabilities. They lack established tools and institutional infrastructure (such as models for contracts and accepted procedures to verify results) which can serve as a basis for the widespread commercialization of reliable services.

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[57] The sector includes: manufacturing, mining and construction.

[58] In 1995, the five largest industrial subsectors were responsible for 76% of the total energy consumptio by industry (79% of the consumption of fuels and 68% of electricity). These industries are: iron & steel (27.7%), food processing (22.6%), paper and pulp (94%), chemicals (9.2%), and aluminum and other non-ferrous metals (7.0%).

The slowness in the structuring of the supply of services and financing for third party project development is today one of the main impediments to the faster diffusion of energy efficiency improvements, both among consumers in industry and as in the service sectors. The consolidation of new agents such as ESCOs and IPPs [59] and the definition of the role of the utilities will be critical steps on the way to transforming the market.

Influencing the Demand for Energy Services

Besides the efficiency of the processes, other "structural" factors can influence the energy intensity of the industrial sector as a whole. An important factor is the relative weight of energy intensive industries. These industries produce basic materials that are at the beginning of a chain of industrial transformations, whose downstream stages are generally much less intensive in energy (especially in relation to the value added). Important examples of energy intensive industries in Brazil are pig iron & steel, ferro-alloys, cement, pulp, basic petrochemicals, aluminum, chlorine and soda.

The expansion of energy intensive industries was very fast in the seventies and until the end of the eighties. Their share of total industrial energy consumption increased during this period, which contributed substantially to total energy growth. There was a strong direct and indirect participation of the State in the development of these industries, including energy subsidies.

In recent years, the expansion of energy intensive industries as a group has been moderated and their share of industrial energy consumption has been diminishing. Until now, no new investments have appeared that might revert this tendency.

However, in the medium and longer term some energy intensive subsectors are likely to grow more vigorously again. In order to exploit the country`s comparative advantages with benefit to the country, it will be important to use realistic prices of key inputs such as energy. A legacy of the old policy promoting heavy industry is an unrealistic structure of electricity rates. Industries connected to the grid at 13.8 kV pay, on average, more than double the price of industries connected at 230 kV. The reforms of the energy sector should decrease this distortion, but the rate structure is a subject which deserves special attention.

The subject of recycling is linked to the use of the products of the energy intensive industries - aluminum, iron, glass, paper and some plastics. The use of recycled material needs much less energy than that produced from the primary natural resource. Recycling is sold mainly as an environmental question, due to the potentially large impacts of production from sources *in natura*. In Brazil, the potential for increasing recycling is relatively large and the country is already the world`s largest recycler of aluminum cans.

<u>Services</u>

The services sector includes commercial (private tertiary sector) and public consumption (offices and public services). It excludes transport services. In comparison with the industrial sector, services have a smaller array of energetically important processes. Another feature is that the profile of consumption is dominated by electricity - 75% in energy terms.

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[59] IPPs (Independent Power Producers) are electricity generators without a concession for public service who operate in the new competitive market for generation. Sanctioned by the Law 9074 of 1995, they should be key actors in the implementation of cogeneration projects, especially those of larger scale. ESCOs (Energy Service Companies) develop projects to increase the overall efficiency of installations, bringing both technical and financial capabilities. ESCOs are less consolidated in Brazil. An IPP can be an ESCO and vice versa. See: (1) A.D. Poole & H. Geller; *The Emerging ESCO Industry in Brazil*; INEE & ACEEE, Rio de Janeiro & Washington DC , April 1997; (2) *Proceedings of the Seminar on Cogeneration and Distributed Generation*, INEE, Rio de Janeiro, May 14 & 15, 1998

The services sector has been increasing its share of electricity consumption - from 19% in 1986 to 22% in 1996. The profile of electricity consumption varies considerably among subsectors (stores, offices, hospitals, etc). Within each subsector there can substantial differences between larger and smaller facilities and among the regions of the country. The average profile therefore depends on the "mix" of the activities included. The available samples are small for statistically significant conclusions at the subsector level.

At the sectorial level it can be verified that a large part of the electricity consumption - generally 50-65% - is associated with the building envelope and some building "utilities" (mainly lighting and air conditioning). [60] In the existing stock of buildings, the potential for retrofits is substantial. There are technologies available for diverse applications that can very substantially reduce consumption compared to typical standards, often on the order of 50% or more. [61] Efficiency gains in other end uses will often allow gains in air conditioning, due to the smaller thermal load inside the building. [62]

As we accompany retrofit projects, it is common to encounter savings of 30-40%, without considering investments in cogeneration. [63] Building retrofit is a fertile field in the short and medium term. There is a large stock of buildings needing general reforms, including new control and automation systems - measures that can be linked to efficiency projects and often largely financed by them.

As was observed for the industrial sector, the weight of energy in total costs is usually relatively small and the level of awareness is low. There are also difficulties in financing and in the supply of services to develope and execute projects. However, this market is probably more accessible than many industrial subsectors.

In new buildings, the reduction in consumption per m^2 can be even greater. Bioclimátically adapted architecture, for example, can reduce the thermal load and increase the use of natural light. In comparison with the industrialized countries, the percentage growth of the building stock will be large. However, the barriers are big. They include architects` and consumers` lack of knowledge of the opportunities of and the frequent separation of the investor from the user. Lines of action lines therefore include the education of professionals and the communication of concepts and potential benefits to investors and consumers.

New construction raises the wider subject of urban planning, that has implications for energy consumption in the residential and transport sectors as well. In the case of buildings, an example of the relationship is the phenomenon of "urban heat islands." The lack of vegetative cover and the low refletivity of many surfaces in urban areas contribute to increase the temperature in comparison with surrounding rural areas.[64] The increased averagetemperature stimulates the demand for air conditioning. There are measures that can reduce the "heat island" effect.

In a tropical country it is appropriate to pay special attention to the demand for "cold". Air conditioning is growing quickly with the increase of income. At the same time, there is a great number of very inefficient systems (for example, large office buildings with window air conditioning units are very common). The entry of natural gas in many cities, together with new cogeneration technologies will create opportunities for new solutions which are qualitatively more efficient - both in retrofits and new buildings.

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60 See R. Lamberts, L.L.B. Lomardo, J.C. Aguiar, M.R.V. Thomé; *Eficiência Energética em Edificações: Estado da Arte*, report to PROCEL, Rio de Janeiro, March, 1996.

61 See R. Lamberts, H. Geller, A.H. Rosenfeld & M.D. Levine, "Energy Efficient Lighting, Windows and Buildings for Developing Countries", AAAS Annual Meeting, 1991.

62 With the climatic conditions which prevail in most of Brazil, the reduction of the thermal load inside buildings is "pure profit". In countries where the winter is cold, heating systems must be used more to compensate this reduction.

63 See A.D. Poole & H. Geller; *The Emerging ESCO Industry in Brazil*; INEE & ACEEE, Rio de Janeiro & Washington DC , April 1997.

64 Increases of 1-4^{o} C have been observed in the USA.

Other types of equipment used in the services sector present a variety of possibilities. Many kinds of office equipment produced and sold in Brazil today follow international standards. For example, many of the personal computers sold have the seal of the North American program "Energy Star." In other cases, like equipment for restaurant kitchens, there is a greater differentiation of the domestic products. The road to improving this latter case can approximate that for home appliances, considered below.

Households

In the residential sector electricity has a large and growing share of final consumption today. The predominant use of fossil fuels is for cooking - mainly with LPG. Space heating, so important in countries with rigorous winters, is almost nonexistent. The profile of electricity consumption is sensitive to income, ownership of appliances and to the region of the country. Table 5-3 shows the typical annual consumption, market saturation and estimated share of total residential electricity consumption for the main home appliances that consume energy more intensively.

Table 5-3
Electricity Consumption and Market Saturation of the Main Home Appliances

Appliance	kWh / Typical year	Saturation [a]	% Total Cons. [b]
Electric shower head	480	0,70	23
Refrigerator	648	0,75	33
Freezer	840	0,07	4
Air conditioner	1680	0,06	7
Washing machine	72	0,22	1
Clothes drier	180	0,03	<1
Electric iron	36	0,75	2
TV *(colored / B&W)*	132 / 84	0,35 / 0,53	6
Lighting	-	1,00	12 [c]
Others	-	-	11

Sources: Jannuzzi and Schipper, "The Structure of Electricity in the Brazilian Household Sector", *Energy Policy* nov. 1991. Mentioned in: R. Lamberts, L.L.B. Lomardo, J.C. Aguiar, M.R.V. Thomé, *Energy Efficiency in Constructions: State of the Art,* PROCEL/Eletrobrás, 1996.
Notes: [a] Saturation in residences with electricity. [b] Percentage of total residential electricity consumption
[c] The cited value in this study was just for incandescent lamps. Other studies show up to 25% of residential consumption going for lighting.

The residential demand for energy services will certainly increase. The saturation of some energy intensive appliances is still low and the first several years of macroeconomic stability have shown that there is a large repressed demand. There was an explosion of purchases of appliances in the first two years, especially among lower income classes of the population that were benefitted by the drastic fall in inflation.

The critical factors in the future evolution of household energy consumption will be the efficiency of the new appliances which are sold and their appropriate use. The potential for reducing the specific consumption of some types of appliances is very significant. Most appliances are now made by multinational companies. This should facilitate the transfer of efficiency improvements obtained in the exterior. Even so, in the market for mass consumer products, experience has shown that is important to have public political action present as happens in the USA and occurs in Brazil with the action of PROCEL. [65]

[65] PROCEL started a project to label appliences for efficiency (refrigerators and freezers) by convincing manufacturers that this would stimulate sales. In practice, labels had a small inpact on sales (few apliences display the label at the

The household demand for *energy services* will grow enormously, but there are some ways to decrease this growth in service demand, without harming comfort or welfare. The bio-climatic adaptation of buildings and neighborhoods can reduce the consumption of energy for air conditioning as observed above. The solutions can be attractive for other reasons as well. The participation of households in recycling campaigns can reduce the demand for energy services, but the gains will appear in the industrial sector.

6. Conclusion

We have shown that Brazil, thanks to policies adopted in the past, has a structure of primary energy use with an important renewable component. As a consequence, the country has one of the lowest coefficients of energy CO_2 emissions/GDP in the world.

This characteristic of Brazil`s energy system, however, is changing as a consequence of the abrupt and deep changes in policy which are occurring. These changes are resulting in the substitution of the fleet of alcohol-fueled cars by gasoline-fueled and the substitution of charcoal by coke in the iron & steel industry. There is also the prospect of a sharp increase in the use of natural gas and coal for electricity generation in substitution of hydro .

The tendency of increasing CO_2 emissions per unit of GDP observed in the Brazilian economy since the begining of the 1990s is, however, not irreversible. As shown here, there is a large potential to reduce energy losses (and CO_2 emissions), both in end use and in the process of transformation of primary energy into final energy use.

With regard to the latter, the reduction of losses, can also be a key factor to make the use of renewable energy economically sustainable in the supply structure. These increases in the energy, economic amd environmental efficiency of the energy sector generally involves the use of “waste” fuels and/or the use of process heat to cogenerate electricituy.

Thus for example, the increasing share of natural gas in Brazil`s supply structure, will not have such a negative effect in terms of global warming if, instead of almost only fueling central station plants to substitute hydrelectricity at the margin, it is more widely used in cogeneration cycles.

With respect to end use, it is clear that the transportation sector will be critical for a strategy to reduce the emissions of greenhouse gases, since this sector alone is responsible for more than 40% of Brazil`s energy emissions of CO_2.

As was shown both for the transport sector and other end use consumption sectors, a broad range of actions can contribute to increasinmg energy efficiency and consequently to reducing CO_2emissions. However these measures will not happen spontaneously without a structured public policy and in the absence of financial resources to leverage these initiatives.

Therfore, it is fundamental that: (1) that there be a structured government policy in Brazil to create a favorable institutional context for these initiatives and; (2) a mobilization of the developed countries to make possible a flow of resources to help sustain and finance these initiatives. This financial support is justifiable not only for ethical reasons, but also because it is fully viable from an economic point of view and Brazil has demonstrated capacity to achieve results.

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stores) but manufacturers were stimulated to increase efficiency and significant progress has been made in the average efficiency of products sold..

Annex A - Ajustments to the National Energy Balance - BEN

Notes on the Conversion to TOE

The National Energy Balance - BEN[66] - is the main statistical source on the production and consumption of energy in Brazil, presents the flows of all the forms of energy used in Brazilian society converted into *tons of oil equivalent* - **toe**, a not very orthodox unit used for historical reasons in the international statistics. [67]

To convert most forms of energy to **toe**, coefficients calculated in the laboratory are used. However, for hydraulic energy the BEN[68] cosiders that 1 kWh is equivalent to the energy contained in the oil necessary to generate this amount of electricity, [69] with 1kWh = 3132 kcal or 0,29 x 10^{-3} toe. This number is about three times higher than the physical conversion, where 1kWh = 860 kcal or 0,079 x 10^{-3} toe. As the electricity in Brazil is practically all of hydraulic origin (95%), this coefficient is also used to convert electricity to oil equivalents.

This method of conversion distorts comparative analyses, above all when one studies the subject of the overall energy efficiency, where the transformations all need to be physically coherent so that the flows in the economy can be been treated a consistent way.

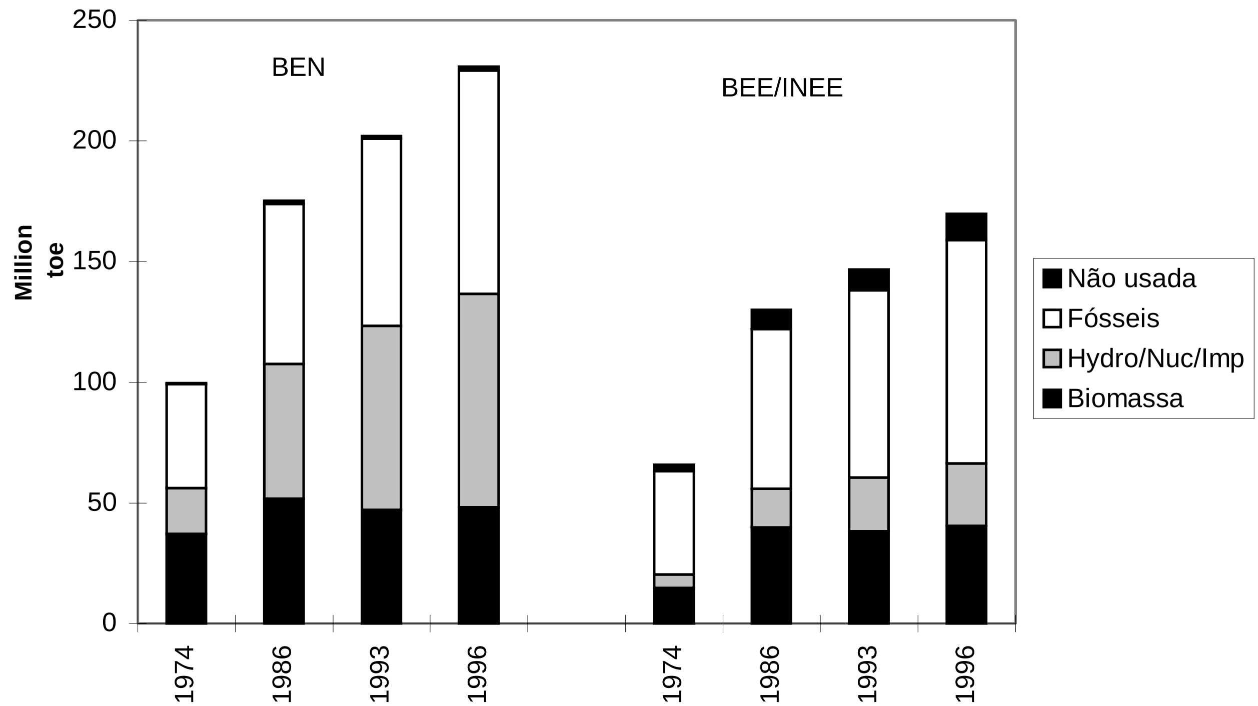
To overcome this problem in the present work, values proposed by INEE[70] have been used. These take the BEN'S data as a basis, recalculating the conversions and make some other corrections to turn the analysis more realistic. Summarizing:

- It adopts the physical conversion coefficient for hydraulic energy and for electricity.
- It considers the existence of losses in the transformation of hydraulic energy into electricity (in the BEN the transformation is considered to be with 100% of efficiency).
- It considers secondary hydraulic energy - spillway losses that could generate electricity. These could used when there is more thermal generation and a system of information in a more agile market.
- It considers the energy in sugarcane residues that today are burned in the fields, but that could be transformed in electricity.
- It excludes residential and agricultural firewood

To give an idea of the effect of the alterations, the graph below compares the values obtained for the contribution of the different primary sources.

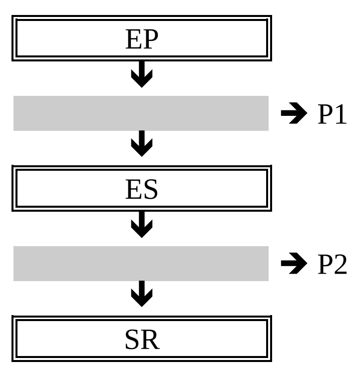
[66] Published by the Ministry of Mines and Energy.
[67] When it was widely accepted that petroleum would be the main source of primary energy in the world (until the decade of the 50s tons of coal equivalent was used).
[68] Approach also used in some international statistics but that is being abandoned.
[69] Equivalent to the average oil consumption of generators in the beginning of the decade of the 70s, with efficiency below 30%. See Wlberg, J. et alii "Consumo Brasileiro de Energia - Dispêndio de Energia Primária no Período 1940-1972"; CNB/CME; Annex to Bulletin 17 of 1973.
[70] INEE is preparing an *Energy Efficiency Balance*, with divulgation planned for early 1999.

Primary Energy: Comparison of the BEN & BEE/INEE



Energy Flows

The illustration alongside is a simplification of Figure 2-1 in the text, showing the variables for the several forms of energy. A basic principle of thermodynamics (the “First Law”) establishes that energy can be transformed, but that it cannot be created nor destroyed. That is:



EP = ES + P1
SR = ES + P2
⇒ SR = EP - P1 - P2

The objective of conservation policy is to reduce losses P1 and P2, thus decreasing EP (Primary Energy), without affecting SR (Energy Services). These objectives are usually translated into coefficients that give a more exact notion of the relative contributions:

$$\eta = \frac{SR}{EP} = \frac{SR}{ES} \times \frac{ES}{EP} = \eta_{SE} \times \eta_{UF}$$

Where the coefficient η measures the global efficiency of the economy and η_{SE} e η_{UF} represent, respectively, the efficiencies in the sector supplying energy and in the sector of final use of energy.

$$SR = \eta . EP$$

$$\text{and} \quad EP = SR / \eta$$

When society demands a new unit of useful energy, ΔSR, if the same efficiency η is maintained, the demand for primary energy, is evidently given by:

$$\Delta EP = \Delta SR / \eta$$

In the hypothesis that an energy policy exists, it is possible to vary η and:

$$\Delta EP = \Delta SR / \eta - \Delta \eta . SR / \eta^2$$

Therefore, the increase in efficiency allows us to substitute a part of the necessary primary energy equivalent to $\Delta\eta. SR/\eta^2$.

If there is a policy of energy efficiency, efficiency can be increased both in the energy supply sector and with final consumers. Thus, the change in overall efficiency $\Delta\eta$, can be calculated as:

$$\Delta \eta \approx \eta_{UF} . \Delta\eta_{SE} + \eta_{SE} . \Delta\eta_{UF}$$

In the case of Brazil in 1996, η_{SE} = 118/160 = 0,74. As developed in the text, the value for η_{UF} UF is still speculative, but it should be in the range from 0.5 to 0.3, that is:

$$\Delta \eta \approx \{0,5 \text{ a } 0,3\} . \Delta\eta_{SE} + 0,74 . \Delta\eta_{UF}$$

Since the increase in the overall efficiency results from crossed effects, it is interesting to consider the two possible approaches to achieve more efficacious results. It should be observed that the increase of efficiency in cogeneration projects has a larger impact because it occurs (Figure 2-1) in the realm of the two sets of technologies.

Annex B - Final Consumption by Sector

The original source for these tables is the National Energy Balance. That information has been adapted in the report being prepared by INEE entitled *Brazilian Energy Efficiency Balance: National Level Accounts*.

Table B-1
Growth in the Final Consumption of Fuels and Electricity: 1974-96[a]

		1974	1980	1986	1990	1993	1996
GDP (US$ 1996)		366,9	546,0	620,9	635,1	658,5	748,7
Rate in interval	*%/yr*		*6.8*	*2.2*	*0.5*	*1,1*	*4,4*
Final Consumption [b]	10^6 toe	54,29	78,17	96,19	101,6	110,4	128,8
Rate in interval	*%/yr*		*6,2*	*3,5*	*1,4*	*2,8*	*5,2*
Fuelss	10^6 toe	49,44	68,73	81,80	84,79	91,86	107,5
Rate in interval	*%/yr*		*5.7*	*3.0*	*0.9*	*2,7*	*5,4*
Fossil Fuels	10^6 toe	38,38	53,88	56,67	61,24	67,65	81,11
Rate in interval	*%/yr*		*5,8*	*0,8*	*1,9*	*3,4*	*6,2*
Biomass	10^6 toe	11,06	14,85	25,13	23,65	24,21	26,34
Rate in interval	*%/yr*		*5,0*	*9,2*	*-1,5*	*0,7*	*2,8*
Eletricity [c]	10^6 toe	4,85	9,44	14,39	16,79	18,57	21,35
	TWh	60.9	118.5	180.7	210.8	233,2	268,1
Rate in interval	*%/yr*		*11.7*	*7.3*	*3.9*	*3,4*	*4,7*

Notes:

[a] Excludes the consumption of the energy sector. Includes the consumption for "non energy uses" such as petrochemical feedstocks, lubricating oils, asphalt, etc.)

[b] Excludes non-commercial biomass in the residential e agricultural sectors.

[c] The coefficient used for the thermal equivalent of electricity is 860 kcal/kWh.

The growth in final consumption by sector is summarized in Tables B-2 and B-3, for electricity and fuels respectively.

Table B-2
Final Consumption of Electricity

		1986	1990	1993	1996
Agriculture	GWh	5004	6666	8005	9729
	%/yr		7,43%	6,29%	6,72%
Industry	GWh	104.361	112.339	122.462	129.194
	%/yr		1,86%	2,92%	1,80%
Commercial	GWh	19.588	23.822	27.403	34.775
	%/yr		5,01%	4,78%	8,27%
Public	GWh	14.849	18.133	20.530	24.065
	%/yr		5,12%	4,23%	5,44%
Transport	GWh	1158	1194	1200	1259
	%/yr		0,77%	0,17%	1,61%
Residential	GWh	35755	48666	53629	69056
	%/yr		8,01%	3,29%	8,79%
		180.715	210.820	233.229	268.078
Total	GWh		3,93%	3,42%	4,75%

Table B-3
Final Consumption of Fuels by Sector

			1986	1990	1993	1996
Agriculture	Total	10^6 toe	2934	3184	3770	4518
	Rate in interval	*%/yr*		2,07%	5,79%	6,22%
Industry	Fossil Fuels	10^6 toe	15578	16570	19223	22795
	Rate in interval	*%/yr*		1,56%	5,08%	5,85%
	Biomass	10^6 toe	18288	16569	17014	18275
	Rate in interval	*%/yr*		-2,44%	0,89%	2,41%
Commercial	Total	10^6 toe	607	-	663	683
	Rate in interval	*%/yr*				1,00%
Public	Total	10^6 toe	153	164	283	471
	Rate in interval	*%/yr*		1,75%	19,94%	18,51%
Transport	Fossil Fuels	10^6 toe	24805	26263	28892	36312
	Rate in interval	*%/yr*		1,44%	3,23%	7,92%
	Biomass	10^6 toe	5437	5702	6063	6961
	Rate in interval	*%/yr*		1,20%	2,07%	4,71%
Residential	Total	10^6 toe	5041	5755	6183	6563
	Rate in interval	*%/yr*		3,37%	2,42%	2,01%
Non Energy	Total	10^6 toe	8959	9716	9767	10874
	Rate in interval	*%/yr*		2,05%	0,17%	3,64%

Note: In those cases where only total fuel consumption is shown, the consumption is dominated by fossil fuels.

Annex C - Market Imperfections

Lack of organized information on conservation opportunities. The subject is relatively new and there are few didactic materials and courses that disseminate concepts for energy saving. There is very little diffusion of understanding of opportunities.

Difficult evaluation of economic results of efficient energy use. The optimized use of energy assumes a "rational" behavior from the economic point of view. It is assumed that the actors will be able to make a comparison between the initial higher investment in efficient equipment and the reduction of expenses with energy. In practice, there are several difficulties in making this comparison, be it the difficulty in calculating the gains (not a trivial operation for non-specialists), be it the consumer's lack of information, or yet the fact that energy expenses are, for the majority of consumers, a small portion of total costs. These problems are aggravated in Brazil by uneven income distribution and by economic instability.

Separation between those who decide on the usage technology installed and the final consumer. Even when there is a perception of the economic benefits, in many situations consumers have no way to reverse some forms of waste generated by the designers of the usage technologies, who may have as an objective price reduction or some other motive. This occurs, for instance, with the boilers installed in buildings, where the builder directs the selection towards the lowest investment.

Lack of efficient equipment. In many cases, the technology to increase efficiency is simple and well known. However, since the initial market in Brazil is small, it is either not offered or is only available at prices substantially higher than in the industrialized countries. This vicious circle has already led to many set backs in expectations.

Absence of explicit costs for environmental aggression. Any use of primary energy resources has, necessarily, environmental costs at local and even global levels. Discussions on how to convert this cost into a financial parameter are far from final solutions or even calculations.

Financial restrictions. The most efficient equipment is usually more expensive. Even if the consumer is aware of the economic benefits of the larger initial investment (which is not obvious - see item above), he may have difficulties in gaining access to credit or might be granted the credit at high interest rates. Since the most efficient solutions tend also to be the more capital-intensive one, one of the basic problems of "volunteer" programs is to induce energy consumers to invest more up front to gain with the reduction in operating costs.