Energy Policies in Brazil

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The relationship between energy and economic development

THE USE OF ENERGY sources and modern technologies of end use has led to qualitative changes in human life, providing the population with both an increased economic productivity and an increased well-being. However, more than the increase in the energy consumption, the services generated by energy are what really leads to an improvement in well-being. Also the purpose for which the energy services are allocated is what ultimately determines the level of economic development that has been achieved.

Energy services can only be acquired by means of a combination of energy technology, infrastructure and supply. Nevertheless, what is really important to the consumers are the usefulness and satisfaction derived from the energy services and the price paid to the energy suppliers in order to obtain those services. For a more detailed discussion on energy services, see Rogner and Popescu (2000).

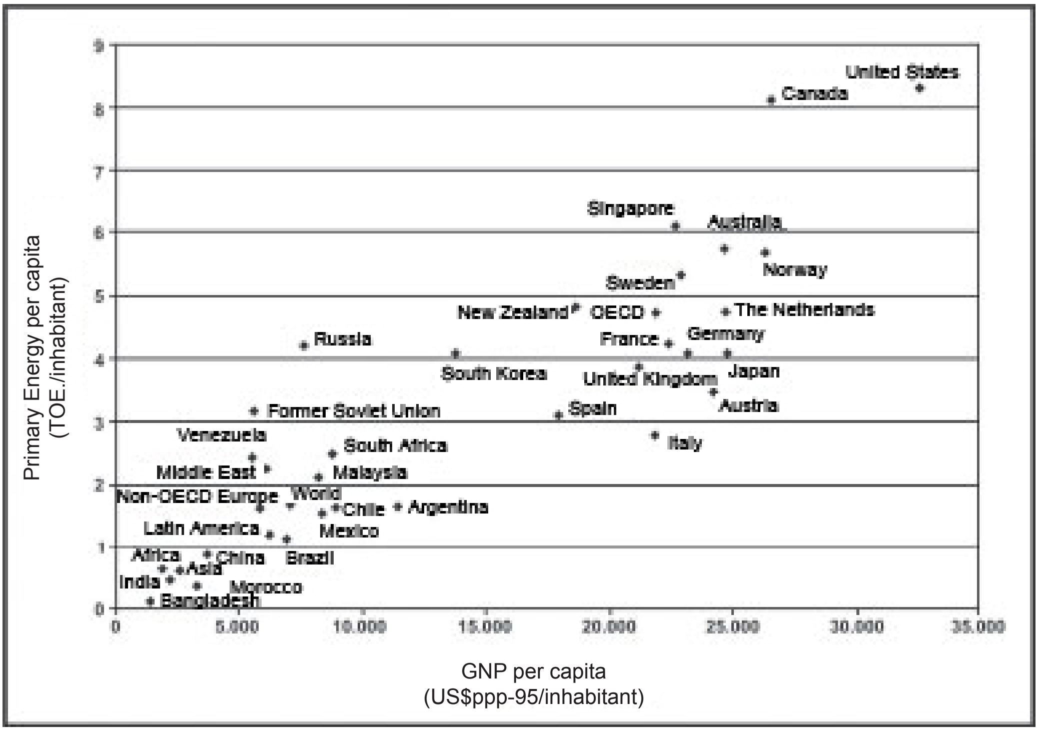
However, the fact that energy – including the modern energy sources – is required to support the economic activities does not imply the existence of an universal fixed correlation between the use of energy (both primary and final) and the economic activities [usually rated by the GNP (Gross National Product)] for all of the several countries (Figure 1).

By analyzing that figure, we can get to the immediate conclusion that it is necessary to expand the energy supply in our country in order to increase its *per capita* GNP. By comparing the GNP of Brazil with that of developing countries with the best economic results, such as South Korea, we can see that it would be quite interesting that Brazil had the same *per capita* GNP (that is, US$ 14,000 instead of the current value of US$ 7,000). According to Figure 1, we can infer that it would be necessary, at least, to double the energy consumption in Brazil in order to achieve such revenue.

Another information deriving from Figure 1 is that, when it comes to the *per capita* primary energy, Brazil belongs to the group of countries with great energy efficiency, for it achieves an economic result (*per capita* GNP) equal to that of the global average (also shown in Figure 1 by the spot "World"), but using only half of the global average *per capita* energy. Nevertheless, it is an indisputable fact that, in spite of the economic efficiency in the use of energy, the country depends on more energy to be able to aspire to a higher growth. It is hard to calculate how much more would be required, because, although the country is economically efficient[1] in the use of energy, such efficiency did not increase since 1977. This result is disappointing when compared to the global average (it decreased from 0.37 to 0.28 units of energy to add 1 US$ to GNP in thirty years), to developed countries, and to some developing countries such as India (it decreased from 0.46 to 0.32). On the other hand, we know that energy, despite being a required condition for growth, is not enough for it. Therefore, the need to implement energy policies stimulating the growth of energy itself and of its efficient use is very clear.

The energy planning must take into consideration, as well, not only the amount of energy that should be made available to society, but also in what region it has the highest priority and how it can become accessible to the less privileged. In addition to that, the energy business is accountable for nearly 8% of the GNP in Brazil, and the investment in energy absorbed, in the early eighties, almost 4% of the GNP, that is, practically one fifth of the domestic investment. Therefore, there is room in the sector to promote the creation of jobs, which may differ in quantity and quality depending on the kind of energy being produced and on where the final energy is made available. In order to do that, we need energy policies that induce activities creating work conditions more adequate to the type of available manpower and that promote the use of technologies and equipment already existing or that can be manufactured or created here.

Figure 1 – Use of primary energy *per capita versus* GNP in some countries and regions of the world in 2000



Source: IEA (2002).

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To generate more energy

Brazil must increase its energy availability in order to ensure a greater economic progress and, consequently, to be able to improve the population's life conditions. As we have already mentioned, the country would probably need, at least, to double its *per capita* consumption and, at the same time, to fulfill the demand due the growth of the population (something like 1% per year).

Such energy should be generated by several sources, since, due to reasons of supply safety, it is more interesting to depend on several primary energy sources than on just one or two. However, it is necessary to respect the economic priorities, often determined by the natural abundance of the sources that are more frequent in our territory. Thus, it is easy to understand the great participation of the hydroelectricity – since Brazil is one the richest countries in water and energy resources[2] – and the modest contribution of the coal – since the country counts on few and low quality reserves.

Historically, Brazil has sought to depend on domestic energy inputs whenever possible, due to the country's great difficulty in generating dollars to import it and the huge expenditure we had by importing oil and its by-products. Nonetheless, as the global trade grows and Brazil increases its active participation in it, we wonder if the quest for domestic sources will remain in force in the future. Thus, by avoiding energy importations, Brazil may be getting farther from the energy optimization and paying a higher price to use its natural resources in a comparison with other countries. In a world where the trade of products is extremely competitive, an expensive energy may be decisive by the time when the country seeks to introduce its products and services in the international market.

Current status of the primary energies

The domestic production of oil and natural gas has grown fast, approximately 10 - 11% per year as of 1980. Particularly, the Marlim oil field, discovered at the Campos Basin in 1984, has become the major Brazilian oil source (40% of the total Brazilian production), increasing the domestic offer of oil. The successful increase in the oil and gas production results from technological innovations developed by Petrobras, by means of specific programs for the exploitation of oil in deep water reservoirs.

Since 1980, natural gas increased its participation in the primary energy sources (FPE - *fontes primárias de energia*) of Brazil, growing at an annual rate of almost 13%. The development of the domestic production of gas usually depends on the association of oil exploitation and production. However, the increase in the development of the whole industry of natural gas demands higher investments in infrastructure in order to transport the imported gas and the gas produced in the continental platform.

In 2003, there were only 8,000 km of gas pipelines for transport and almost 9,000 km of gas pipelines for distribution, being the latter concentrated at the Southeastern region of Brazil. The supply of natural gas at the Southern region became available no sooner than in 2000, with the operation of gas pipelines that bring the fuel from Argentina and Bolivia. The Argentinean pipeline transported approximately 2.1 million cubic meters a day in 2001, with an increase to 4 million m^3 / day forecasted for 2006 and to 6.9 million m^3 / day for 2008; in 2003, the Bolivian pipeline had a transporting capacity of 30 million m^3 / day.

The development of the second biggest domestic reserve of natural gas (in Urucu) is restricted to producing and processing a small fraction of LPG (liquefied petroleum gas) for local consumers, due to the lack of a distribution network. Petrobras is presently studying the feasibility of two gas pipelines from the Urucu gas reservoir to Porto Velho, capital of the state of Rondônia, and Manaus, capital of the state of Amazonas. The inauguration of the Bolivia-Brazil Gas Pipeline in 1999 was a major step towards the introduction of the gas in Brazil, but the amortization of the investments in infrastructure will partially depend on the development of a critical mass of large industrial consumers.

The generation of electric power in Brazil grew at an annual average rate of 4.2% between 1980 and 2002, and the hydraulic energy has always prevailed. The other technologies generating electric power are the nuclear, gas, coal and diesel oil ones, although none of them is applied in a percentage higher than 7%. The introduction of the biomass, nuclear energy and natural gas decreased the hydroelectricity share from 92% in 1995 to 83% in 2002; but the strong and constant growth of the demand for electricity requires, in absolute terms, over the double of the current generation of hydroelectricity, even at lower growth rates than the other generation options.

A particular characteristic of Brazil is the large scale industrial development and use of biomass energy technologies (see Rosillo-Calle and Bezzon, 2000). The production of ethanol from sugarcane and the charcoal produced from eucalyptus plantations, the co-generation of electric power from bagasse, and the use of the biomass energy in the pulp and paper industries (barks and tree residues, sawdust, black liquor, etc.) are expressive examples of that characteristic. The utilization of biomass in Brazil results from a combination of factors, including the availability of resources of inexpensive biomass and manpower, the fast industrialization and urbanization, and the historical experience with large scale industrial applications of biomass energy.

Brazil has the ability of increasing its utilization of biomass energy, possessing a considerable potential for energy diversification. A great portion of the soil is available for the expansion of artificial forests and energy plantings, with a limited impact on the production of food. Only the *cerrados*[3], with vegetation that is similar to that of the savannas, add over a hundred million hectares (ha) and have only started to be explored, especially by soy plantations, which are developed in less than 10% of the region.

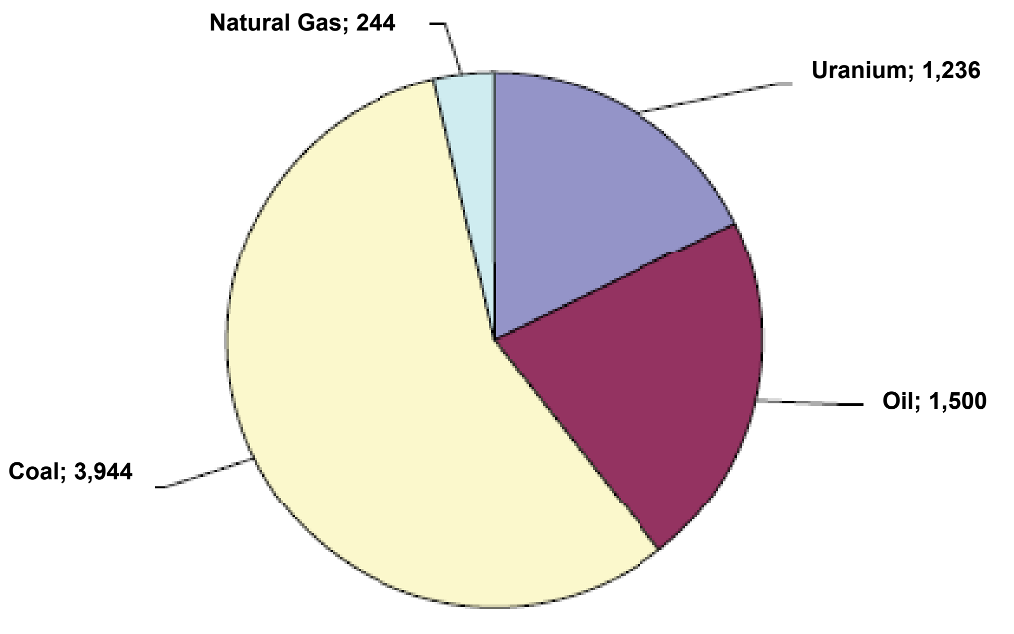
According to ANEEL (*Agência Nacional de Energia Elétrica* – National Agency of Electric Power) (2002), in January 2002 there were 159 biomass thermoelectric power stations in the country[4] with an installed capacity of 992 MW, or 8% of the thermic energy of the country. The majority of those power stations – corresponding to approximately 952 MW, located mainly in the state of São Paulo – use sugarcane bagasse. There are four power stations with a combined installed capacity of 25.5 MW and that utilize residues from the lumber industry, and three other power stations (14.4 MW) that burn rice residues[5]. The total is of

Control room of the Furnas Hydroelectric Power Station (State of Minas Gerais) approximately twenty new biomass projects, which are going to add 105 MW to the total of the biomass sector (ANEEL, 2002).

Energy reserves

Brazil counts on relatively abundant energy sources, as shown in Figure 2, which does not take into consideration the hydroelectricity or the new and renewable energy sources (small power stations, wind farms, biomass energy, solar energy, etc.). Only the hydroelectric potential regarded as commercially exploitable represents 236 million tonnes of oil equivalent (TOEs) per year, while the total consumption of primary energy sources was of 201 million TOEs in 2003, with 41% from a renewable origin (hydroelectricity with 14%, sugarcane bagasse with 12%, firewood and biomass residues[6] with 13%, and other with 2%).

Figure 2 – Reserves* of non-renewable primary energy in millions of tons of oil equivalent – Brazil 2003



*The reserves concern to those occurrences identified and measured as economically and technically recoverable with the current technologies and prices.

Of the total of nearly seven billion TOEs regarded as reserves, there is a great uncertainty about the use of a portion of them. The exploitation of hydroelectricity, for instance, has never surpassed 70% of the reserves in any country of the world (IPCC, 2001), showing that there are barriers, other than the economic ones, which establish a limitation to the exploitation of the total reserves. Those barriers might restrict the utilization of the reserves quantified in Figure 2, and the utilized percentage might be lower than the aforementioned historic value, mainly for the coal and uranium – whose utilization is presently quite moderate, indicating the existence of large barriers against their use. Assuming a maximum exploitation of 50%

of the reserve of those two inputs and of 70% of the oil and natural gas reserves, it becomes clear that, in order to fulfill the current consumption (201 million TOEs), the reserves of non-renewable energy (which have decreased from nearly seven, shown in Figure 2, to 3.8 billion TOEs) will suffice for nineteen years. Considering the hydroelectric potential and the new and renewable sources[7] supplying 40% of the energy consumed yearly (that is, the contribution in 2003), the reserves would last a little longer – 32 years, if the present consumption is kept. As a matter of fact, there will be an increase in the consumption in the future, which implies a decrease in the reserves' service life. On the other hand, a decrease in the reserves increases the price, allowing the incorporation of a portion of the currently non-economic resources[8] in the future reserve.

When it comes to hydroelectric resources, Brazil finds itself in a relatively better situation. The total technical potential is estimated in approximately 260 gigawatts (GW), which, in terms of the *per capita* potential of the hydroelectric production, is equivalent to 6.7 Megawatt-hours (MWh) / year / inhabitant, way higher than the annual average of 2.4 MWh / year / inhabitant. About one third of the total potential has already been built. Presently, Brazil is the second biggest hydroelectricity producer in the world.

Energy and environment

Brazil possesses a relatively "clean" energy system, counting significantly on renewable energy sources, such as biomass and hydroelectricity. Nevertheless, the most important issue is that of knowing how the fossil fuels are used to fulfill the needs of intensive energy of the industries in the manufacturing sector, of the increasing urbanization, and of the fast growth in the transportation sector, without causing an excessive damage to the environment.

Local atmospheric polluting agents

The local atmospheric polluting agents generated by the energy systems in Brazil include, mostly, SO_X, NO_X and CO. The majority of SO_2 emissions in Brazil results from the use of oil fuels with a high content of sulphur in the industrial sector, from the use of coal in the steel manufacture and of the diesel fuel in transports. The SO_2 emissions suffered a great decrease in 1997, resulting from the implementation of the diesel oil improvement program and from the utilization of light vehicles using straight ethanol (Schechtman *et al.*, 1999).

Due to the predominance of hydroelectricity and, in a smaller extent, of the nuclear energy in the sector of electricity generation in Brazil, the energy sector does not emit great amounts of sulphur oxides[9]. However, there are different impacts resulting from the SO_2 emissions, depending on the emission sources and the geographic area. Those include acid rain in a great extent, sulphates aggregated to light particles generated by diesel-fueled vehicles in urban areas, and a direct intoxication by SO_X in the surroundings of industrial complexes. Therefore, the SO_X emissions should be evaluated locally, not only on a nationwide basis.

The CO emissions in Brazil mostly result from the use of biomass in the residential sector, specifically from the burning of firewood for cooking, and, in the industrial sector, from the burning of firewood used in furnaces. Since the amount of the utilized firewood has substantially decreased along the last two decades, the CO emissions were considerably reduced although the charcoal supply has maintained its importance in the steel industry. The CO emissions are still important polluting agents, due to the burning of firewood in the poor communities.

Global polluting agents

The emissions of Greenhouse Effect Gases (GEGs) in 2000 were 20% higher than in 1990, and can increase even further as renewable charcoal is replaced by the foundry coke, and with the expansion of natural gas-based electric power generation. However, this trend can be counterbalanced or even reverted by the introduction of flexible fuel vehicles (which can function with any combination of gasoline and ethanol), the expansion of biomass-based co-generation and of other new renewable energy options, such as wind farms and small hydroelectric plants.

Table 1 – Estimates of GEG emissions caused by the use of energy (fossil fuels and non-renewable biomass) - (Based on Marland *et al.* [2003]) and changes in the use of the soil and deforestation (Based on UNFCC, 2005 [Annex-I countries] and FAO, 2003 [non-Annex-I countries, basis-year 2002]).

	Country	Emissions of Fossil Fuels (MtC_{eq}) 2002	Emissions Caused by Changes in the Use of the Soil and Deforestation (MtC_{eq}) 2002	Total Emissions (MtC_{eq}) 2002
1	United States	1981	-188	1703
2	China	762	-160	601
3	**Brazil**	**84**	**347**	**431**
4	Russian Federation	392	-12	380
5	Japan	363	0	363
6	India	363	0	363
7	Germany	277	4	281
8	Canada	199	-6	194
9	Indonesia	74	117	190
10	United Kingdom	173	1	174

It is important to mention that, despite the increase in the GHG emissions resulting from the use of energy, the Brazilian emissions are still quite low as compared to the ones of the developed or over-populated countries (see Table 1). In 1998, for instance, the Brazilian *per capita* CO_2 emissions generated by the use of energy reached 1.94 tCO_2 / inhabitant (of carbon dioxide only), way below the global average and the OCDE countries average, which were of 3.89 and 10.93 tCO_2 / *per capita*, respectively. Unfortunately, this does not occur with the GHG emissions caused by deforestation. It is significant to point out that there are countries performing vegetation replacement, while Brazil is the leader in deforestation (see Table 1).

Finally, it is important to emphasize that the biggest portion of greenhouse effect gases in Brazil derives from non-energy sources, such as agriculture and cattle farming, changes in the use of the soil and forests, and treatment of residues. Between 1990 and 1994, changes in the use of soil, in the consumption and transformation of energy, and in the production of cement, in this very order, were the major sources of the carbon dioxide emissions in the country (MCT, 2002). The changes in the use of soil, by themselves, represent two thirds of the Brazilian *per capita* emissions of carbon dioxide. On the other hand, the planting of new forests, especially of eucalyptus and pines, represents the most important factor in the removal of carbon dioxide in the sector.

The Brazilian energy future

Based on the past results, the current availability of the energy reserves, and the policies of economic development and preservation of the environment, it is possible to outline scenarios for the Brazilian energy expansion.

The great number of variables involved in the energy planning demands the existence of complex energy policies. Those policies are increasingly important, for the energy sector that depends on private investments. Therefore, the government's role gets more and more restricted to the expansion management, by establishing policies in the society interest, which would not always be among the priorities of the private sector.

There is plenty of room for the magnification of the government management, since, although existing, the actions demanding a greater efficiency in the final use of energy and prioritizing kinds of energy associated to the generation of more jobs still present modest results. For instance, the utilization of biomass, in addition to being commercially competitive as a source of liquid fuel, allows the hiring of a much greater number of employees than the oil option. Despite being politically relevant and acknowledged, this fact is not explicitly taken into consideration in the energy expansion programs.

The definition of the industrial profile has a great impact on the amount and kind of final energy that we will have to produce. Historically, the country is a great producer of energy intensive products (pulp and paper, iron and steel, aluminum, etc.) and the change of this profile to less intensive products might alter, in the long term, the demand for energy.

International aspects, associated to the importation and exportation of energy, also require the establishment of policies in the planning area. For example, decisions on the advantages of producing energy in the country or of importing it are, usually, not present in the energy planning.

The quest for the self-sufficiency in oil is a traditional policy of the energy sector, but it is based on the need to reduce financial expenditures with importations. However, as the importation issue lost its importance due to the great internal production of oil, other facts should be taken into consideration. The investment in oil consumes a big portion of the available funds in the country, and a reduction in this investment could release resources for other and economically more productive purposes, which could generate products and services for exportation.

The same argument can also be applied to natural gas. Along recent years, Brazil identified large reserves of natural gas in its Southeastern region. In order to make its use feasible, big investments should be made in the systems of transport for the product (gas pipelines and compressors). In a parallel with the national energy potential, we could use and even expand the supply of gas from Bolivia. But, considering the recent political problems in that country, great uncertainties are being detected about the advantage of importing gas from Bolivia.

Unlike oil, natural gas is a safer product on what concerns to the guarantee of international commercialization. The fact that its transport demands the construction of gas pipelines creates strong commitments between the supplier and the consumer. Moreover, the commercialization usually occurs between geographically adjoining nations, which restricts the buying market and allows a deep knowledge of the political situation of one country by the other.

Therefore, the definition of the interest on the importation is not determined only by the supply risk. It has to be made based on economic aspects associated to energy and economic aspects associated to the development of the countries. In the Bolivia case, it is necessary to consider the economic options of the country and to assess if it is likely to renounce the gas commercialization. It is necessary, as well, to consider that reducing the country's gas exportations will reduce the country's ability to develop, increasing social tensions and decreasing its willingness to import Brazilian products.

It is also necessary to introduce policies that allow the control of gas consumption growth in Brazil. In spite of the great increase in the use of gas in the country, the sector of electricity generation, which would be its major user, has presented a moderate and unstable growth. If gas-based thermoelectricity is Brazil's great option, the domestic reserves, although existing, might result insufficient in the long term. In this planning option, we will certainly need imported gas, and the existence of a great availability of this product in South America fully justifies the construction of an international gas network in this region.

Another issue with an international dimension is the increasing use of renewable liquid fuel. For environmental reasons, the ethanol and biodiesel have been increasingly commercialized in several countries. Despite the environmental interest, the major economic argument is the possibility of producing fuel locally, generating jobs for the rural population.

The production of energy from biomass at competitive prices demands a number of minimum natural conditions (availability of extensive cultivable areas, a high rainfall rate, temperature and insolation typical of tropical countries) and economic conditions (mainly an inexpensive workmanship), which restrict this

São Paulo, Av. 23 de Maio, at 10:00 am: vehicles contribute to further pollute the city's air.

production in a large scale to a few countries. Brazil is one of them, and that is why it has to define more aggressive exportation policies in this area[10].

Conclusion

Energy sources are crucial inputs for the economic and sustainable development of Brazil. However, the use of this energy in the production of the services it provides is as important as its internal availability at competitive prices. It is also important to point out that the physical availability of the exploitation of such energy, either for economic reasons or for its easy utilization as a primary energy source, determines the interest of the consumer market. Brazil counts on large resources, but the utilizable reserves are relatively limited. Luckily, the participation of the renewable energy, mainly in the form of hydroelectric and biomass energy, allows the increase of the reserves duration and forecasts a sustainable energy development.

The dependence on external energy sources, especially when their quality is highly interesting for the consumer, as it is the case of the natural gas, and mainly when they are originated from neighboring countries, does not represent a major risk and presents economic advantages to the country. On the other hand, a strong dependence on oil involves a higher risk, which should be minimized.

Renewable sources are regarded as more adequate solutions, and our country counts on the privilege of having them and using them extensively.

The ability to manage this ensemble of advantages, risks, opportunities to generate jobs, and a good allocation of financial resources, requires another ensemble of public policies, since a large portion of the energy production is in the hands of the private initiative.

Notes

1. Economic efficiency defined as energy consumed to produce an economic value unit, measured as primary energy / GNP.
2. The abundance of water is not a sufficient condition for the generation of hydroelectric energy, but it is necessary. Brazil has a topography reasonably propitious for hydroelectric generation. All ingredients added, the country possesses a good hydroelectric potential.
3. The *cerrado* is constituted by vegetal formations with variable aspects and features, especially by small and twisted trees that become covered by creepers. It covers about one fourth of the Brazilian territory and is one of the richest ecosystems of the Earth.
4. The actual number is greater still, for there are over three hundred sugar mills in operation. The ANEEL data are based on officially registered power stations, and some stations have not been officially registered as energy producers as yet.
5. This survey included only half of the sugar mills in the country – that is, about 170 of the total of 330.
6. As a matter of fact, a portion of those inputs should not be regarded as renewable, for having resulted from the deforestation of natural forests. This portion is small and does not substantially alter the value of the renewable fraction of our energy. A more accurate number could be something about 36-38%, instead of the 41% listed in BEN (2004).
7. This definition includes the energy generated by small hydro plants, by the wind, and especially by biomass as an input for the production of ethanol and electric power. Other new and renewable sources used in the country include photovoltaic and thermal solar energy.
8. Resources are those occurrences of energy sources with a lesser geological certainty and / or economic characteristics, but which are regarded as potentially recoverable with the forecasted technological and economic development.
9. In 1980, the SO_2 emissions were of 2.133 kt, the NO_x emissions were of 1.423 kt and the CO emissions were of 19.403 kt.
10. It is obvious that the exportation does not depend exclusively on the willingness of the country that produces the product. It depends on the willingness of the other countries to buy the product as well. Presently, ethanol is the only energy product that faces protectionist barriers in the United States, the European Union and other countries. However, those barriers can be overcome if Brazil shows its interest by means of efforts of advertisement about the product's quality and of diplomatic negotiations in which some advantage should be granted to the potential importers.

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ABSTRACT - Energy is an essential ingredient to life in modern society. The expansion of Brazil's energy infrastructure, both for production and consumption, will demand large investments. This, in turn, requires government planning of energy-related activities, which are usually implemented by the private sector.

This presence is essential for: 1. Fulfilling society's demand for more and better energy services; 2. Stimulating participation in sustainable and enduring energy sources; 3. Prioritizing efficient energy use in order to disengage capital for more productive areas of the economy and to preserve the environment; 4. Using investment in energy as a source of jobs and a stimulus to domestic industries; 5. Incorporating foreign inputs into the energy portfolio when it is commercially and socially advantageous for Brazil

– including the exportation of energy products and services; and 6. Generating energy from various sources to reduce the risk of eventual shortages, in keeping with the country's available energy reserves.

KEYWORDS - Energy Planning, Sustainable Development, New and Renewable Sources, Natural Gas, Public Policies.

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