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ENERGY ISSUES AND POLICIES IN BRAZIL

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I. INTRODUCTION

Brazil is a modest energy consumer by US standards: total energy consumption in 1980 was 5.1 QUADS (as compared to 75 QUADS for the United States); since its population is half of that of the US (120 million) average per capita consumption in the US was approximately 7.5 times greater than in Brazil.

This average however hides the fact that there are extremes of wealth and poverty in Brazil: many districts in the great industrial cities of the Southeast (São Paulo, Rio de Janeiro and Belo Horizonte) are modern and prosperous comparing favourably with many cities in the industrialized countries. At the same time there are large slums around these cities and the rural population, mainly in the Northeast, is very poor and destitute. One could almost say that there are two countries one within the other or a "Belgium inside India" in which 20 million people have a standard of life comparable to urban dwellers in Italy or Belgium and the remaining 100 million comparable to the peasants in India.

One has in the same developing country a "modern sector" which consumes commercial sources of energy (hydroelectricity, coal and petroleum) and a "traditional sector" which depends on non-commercial sources of energy (mainly fuelwood).

In the last 15 years economic growth has been very high but has taken place mainly in the urban centers which have grown explosively while most rural areas have remained stagnant.

Brazil has meager petroleum resources and domestic production has not covered more than 20% of consumption. Since 1973 this has become a fundamental problem in the development of the country; initially it was attempted to solve this problem by heavy borrowing abroad which went basically into paying the petroleum needed for further expansion of internal consumption, as it happened to many other developing countries. Hydroelectric resources are abundant in Brazil so electricity production has not been a problem; the "energy crisis" was a "liquid fuel crisis" right from the start.

When further borrowing to pay for the petroleum bill became difficult - the external debt climbed to the mark of 50 billion dollars - conservation and attempts to substitute petroleum derivatives were the strategies followed.

The first policy was to penalize gasoline consumers (i.e private automobile owners) in order to save gasoline. Prices of petroleum derivatives and most other energy sources are administered by the Government in Brazil allowing strong regulatory actions.

Pricing policies led to some extent, to a more efficient use of gasoline in better cars but basically shifted around types of consumption since the truck fleet converted to Diesel. It is rather unfortunate that the "oil problem" was faced in 1974 with determined policies aiming at conservation of gasoline while the same did not happen to Diesel or fuel oil. In fact, these fuels remained subsidizied until recently.

The second policy was a determined effort to find substitutes for petroleum; the impressive increase in the production of ethanol (ethyl alcohol) from sugarcane and its use to replace gasoline has succeeded in showing the way for a series of other initiatives leading to the replacement of petroleum derivatives by fuels derived from biomass.

Such success was achieved because an unexpectedly strong coalition of government technocrats, energy analysts and industrialists from various sectors was formed and able to overcome opposition from more conservative sectors.

The goal to achieve "energy autonomy" became a common denominator among many sectors in the country, with reasonable chances of success.

The purpose of this paper is to analyze such initiatives most of which are applicable to a number of other developing countries. Our emphasis here will be in the dynamics of the movement away from oil and the desire to base the development of the country on locally available resources such as hydroelectricity and biomass derived fuels.

We will discuss successively Energy Resources, Energy Consumption, Issues and Policies, Energy Projections and Social Issues. In the Conclusions we will discuss the relevance and applicability to other countries of policies followed in Brazil.

II. ENERGY RESOURCES

A general view of the energy resources in Brazil can be gained by examining Table 1 which gives measured and infered reserves of the most important energy sources (1). Numbers in this report are updated from other information available in the literature. A discussion of the numbers for each of the energy sources of Table 1 is given below.

A. Petroleum and Natural Gas

The presently known reserves of petroleum and natural gas (2) are 1.286×10^9 barrels of petroleum and $47 \times 10^9 m^3$ of gas. Most of the country was surveyed by PETROBRAS, the state owned enterprise which has the monopoly for petroleum exploration. The most promising findings are on the continental platform in the Southeast part of the country (Campos basin, near Rio de Janeiro).

The total number of operating wells is 2,142 of which 1,647 inland and 495 offshore. The total number of wells drilled is 5,276 with a total of 7.95 million meters; the average amount of oil found is therefore 154 barrels/meter drilled which compares favourably with the present yield of 60 barrels/meter in the United States. The rate of oil findings for each million of meters drilled (2) has been very irregular as shown in Figure 1.

Oil exploration is in its infancy in Brazil; the total number of meters drilled in the US is approximately one billion meters, i.e. more than 100 times the amount drilled in Brazil which has approximately the same territorial extension.

In the first 30 million meters drilled in the US the average amount found was 700 barrels/meter (3).

B. Coal

Coal is not abundant in Brazil being found in significant quantities only in the Southern States (Rio Grande do Sul and Santa Catarina). The most important deposits are in Candiota (Rio Grande do Sul) where more than half the existent reserves are located. Generally speaking all the coal is of the bituminous type; prewashed coal has an ash content higher than 40% and can only be used for non-metalurgical purposes such as steam production.

The information on the reserves as of 1979 (4) is given in Table 2.

C. Shale

The known shale oil reserves (5) are given in Table 3; most of the deposits contain 4 to 8 percent oil. The recoverable oil is estimated to be approximately 500×10^6 TEP, several times higher than the petroleum reserves.

D. Hydro

The country is well endowed with hydroelectric resources (6) which are spread out over the country with a concentration in the North as shown in Table 4.

This potential is evaluated in such a way as to produce firm power, i.e. average power level that is guaranted even under the worst climatic conditions ever recorded, at a 50% load factor. This corresponds to 932 Twh/year, equivalent to 271,000 TEP/year or $5,5 \times 10^6$ barrel equivalent of oil per day.

E. Nuclear

Important findings of U_3O_8 (7) have been made in the last few years as shown in Table 5. Most of the reserves are located in Poços de Caldas (Minas Gerais) and Itatira (Ceará).

Although the situation regarding uranium oxide reserves has improved, one should point out that 1/2 of the quoted reserves are infered. The economic feasibility of exploiting most of them has not been assessed yet.

F. Biomass

Brazil is a large tropical country which was heavily deforested except for the Amazonas forest. The distribution of land uses (8) is shown in Table 6.

We estimate that land for crops could be increased to 200 million hectares of which possibly 10% (20 million hectares) could be used for energy purposes in the form of woodfuel, charcoal, ethanol from sugarcane, ethanol or methanol from wood, and vegetable oils (as a possible substitute for Diesel oil).

This is a very conservative estimate because very extensive forested areas and marginal lands could be converted into energy forests.

Assuming as a working hypothesis, a dry biomass yield of 10 ton/ha/year, from which one can produce 2 tons of petroleum equivalent fuels per hectare/year, one concludes that it is possible to obtain 40,000x10^3 TEP/year from this resource. This is approximately the current oil consumption in the country.

III. ENERGY CONSUMPTION

Energy consumption in Brazil has grown at 7.7%/year (1) since 1969, i.e. with a doubling time of 9 years; this is a very large rate of growth. Even higher growth rates have been achieved in the hydroelectric sector where growth has reached 13.4%/year as can be seen in Table 7. The absolute amounts of energy consumed in 1979 and percentages are also given in this Table.

What is interesting to analyze here is the evolution of primary energy consumption, i.e. the "dynamics" of energy consumption. The available data (9) starting in 1940 is shown

in Figure 2. As one can see in this figure there was a very rapid shift from "traditional" to "modern" fuels in the period 1940-1979.

Oil and gas represented 9.2% of total consumption in 1940; this fraction increased to 41.1% in 1979, while biomass represented 75% in 1940 and decreased to 24.7% in 1979. The modernization which took place in Brazil in this short period of time means, in energy terms, the adoption of a "petroleum economy" and an abandonment of traditional fuels.

The adoption of a petroleum economy was not matched by the production of petroleum to sustain this type of development : 81.5% of petroleum used in 1979 was imported and only 18.2% produced from local fields (1).

IV. ISSUES AND POLICIES

The consequences of the dependence on petroleum imports on the balance of payments have become disastrous since 1974 as can be seen in Table 8 which gives petroleum imports and the balance of payments (10).

Petroleum imports which corresponded to less than 10% of the exports before 1973, increased to more than 50% of total exports in 1980.

Although a great effort - which was quite successful - was made to increase exports, this was not enough to upset "deficits" in the trade balance which rapidly plunged the country into a 50 billion dollars external debt.

The external trade balance by itself was not unduly high but the need to increase exports led to the influx of foreign capitals in large amounts which added to the external debt and therefore to the amount of debt servicing in a kind of vicious circle from which it turned out to be difficult to escape.

The economic policies of the brazilian Government have been entirely dominated by these concerns. Nominally, at least, the short term objective of the Government has been to obtain dollars abroad either by increasing exports or by attracting new investments, gaining the time needed to introduce structural changes in the productive process and in the nature of the exports in which petroleum derivatives could be substituted (11).

Since the need to increase exports in the industrial sector requires the increased use of petroleum derivatives (and imported machinery), a great effort has been directed in the past at exporting products of the extractive sector (iron, manganese, and other minerals) or agricultural products (coffee, soyabeans, etc.) which are not very energy intensive as compared with manufactured goods.

This is a very different policy from the one followed by Japan and West Germany which have also to import their petroleum but which are capable of exporting manufactured goods transfering therefore to the purchasers of these goods the increased cost of petroleum.

It was not a lack of will that kept the brazilian exports at the level it is now (both qualitatively and quantitatively) but the lack of alternatives.

Actually what has been witnessed since 1974 in Brazil is a modest effort in conservation and a greater effort in substitution of some petroleum derivatives but little was achieved in structural changes. Such changes would involve social readjustments which are not attractive to the upper middle class that constitutes the "Belgium inside India" refered to in the Introduction.

Conservation was introduced mainly through pricing policies which were followed later by substitution of gasoline by alcohol (ethanol).

It was only in 1980 that the amount of alcohol produced reached 60,000 barrels per day which is equivalent to 5% of the petroleum consumed in the country (although it corresponds to 20% of the total consumption of gasoline on a replacement basis).

A. Petroleum conservation through pricing policies

Pricing policies had a great impact in the consumption of gasoline in the period 1975-1979 before the production of alcohol became significant.

Since the main purpose of the energy policies was to decrease the amount of imported petroleum(and not only one of its derivatives such as gasoline) it is necessary to act on the total size of the "pie" and not only on one of its slices.

Starting in 1974 the Government increased the price of gasoline to a very high level but kept the price of other derivatives (Diesel and fuel oil) very low and in effect subsidized (Figure 3). The reasons for this are well known: individual automobile owners who use their cars for recreation cannot transfer the additional cost of gasoline to other sectors of society while Diesel and fuel oil users (in transportation and industry) can do it, increasing prices of their services and products thus contributing to inflation. As an example it is interesting to compare the present cost of gasoline and Diesel oil in Brazil, US and France as shown in Table 9.

The high price of gasoline had dramatic effects on its consumption as can be seen in Figure 4. It levelled off in 1974 because all the gasoline truck fleet, which was large, shifted to Diesel.

In addition to that the average consumption per vehicle was reduced by almost a factor of two between 1974 and 1979 due to improvements in the car economy, better roads, better traffic systems and changes in driving habits encouraged by the high cost of gasoline.

Two cars per family have also influenced the average consumption per vehicle. It is interesting however to point out that the profile of derivatives from the refineries of Petrobrás did not follow the changes in consumption. This profile for the year of 1979 was the following: gasoline 23,1%, Diesel oil 29,66%, fuel oil 31,76%, LPG 6,26 and others 9,22%.

This profile has changed little since 1975 except for the fact that the gasoline fractions has decreased from 30% down to

23% while use of naphta for petrochemical purpose has increased to 6%

Probably one of the weakiest points of the pricing policies has been the lack of decision on implementing changes in the refining profile through changes in the cracking patterns; Petrobras has refused to do that on the grounds that investments needed are high and that the Company was making good business selling excess gasoline abroad and purchasing heavy oils in return; it has argued also that total consumption of light components of petroleum (naphta) will grow because of petrochemical projects already in march and that a new cracking profile could hurt these projects (11).

A recent important development which took place in early 1981 was the dramatic increase in Diesel and fuel oil prices (Figure 3).Diesel oil is now above international levels, but is unclear yet how this will affect Diesel consumption,since they are no options for its substitution. Fuel oil is being substituted by other fuels.

It was realized early in the process that pricing policies in an expanding economy could shift around the use of petroleum derivatives but did not reduce the total consumption. In the period 1975-1980 petroleum consumption did not in fact decrease and this is expected to happen only when the alcohol program begins to produce very significant amounts of fuel in the next few years.

Since one seems stuck to the present refining profile a broad range of steps of conservation measures could reduce consumption of the three main derivatives of petroleum (gasoline, fuel and Diesel oil). These have not been too successful as we will see in what follows.

B. Petroleum conservation through other means

The climate in the Southeastern part of Brazil where most of the population and industrial activities are concentrated is rather mild.

This means that heating is not needed in the winter and that the amount of air conditioning in the summer is not very large except in some coastal regions. This is of course a great advantage regarding energy consumption and limits the possibilities of conservation in this area.

Industrial equipment in its great majority is either imported or copied from similar equipment in industrial countries; as a consequence the patterns of consumption of energy are quite similar to industrialized countries. This can be seen in Figure 5 which shows the embodied energy (in kcal/cruzeiro) for the US and Brazil.

The data for the US includes 92 sectors of the economy evaluated for 1967 (12) and the data for Brazil was obtained from the 1970 census (13).

The average for the whole of the economy is different, the brazilian one being less energy intensive, but the distribution among sectors is very similar for the two countries: the average embodied energy for the US is 22,500 kcal/dollar and 15,750 kcal/dollar in Brazil (1970 dollars).

What this means is that conservation policies in transportation and industry cannot be very different in Brazil and the US.

Conservation of Gasoline(6)-Gasoline consumption is distributed the following way: 59% in intermunicipal driving and 41% in city driving,all in automobiles for individual use. Although most cars in Brazil are of the compact and sub-compact type with reasonable fuel economy (around 10 km/liter) - which could nevertheless be improved - savings were felt by the government to be achievable in other ways such as the improvement of the average speed of city driving, limiting speeds to 80 km/hour in the roads, closing service stations in the weekends , encouraging the use of buses and raising talk in the highways. It is difficult to estimate reliably the economy which resulted from these initiatives but they are probably small.

Conservation of fuel oil (6) - 88% of the fuel oil is consumed by industry, 6% are used for electric generation and 6% in transportation. Industry is therefore the sector in which significant economies can be made. Since brazilian industry is quite modern one expects here the kind of economies that are possible in the industrialized countries.

A recent study made by industry (11) indicates the possibility of conservation of 46,000 barrels per day in 1985, relative to the amount extrapolated to that year without conservation measures.

Investments to achieve these savings have been estimated on the basis of the return of investment by the oil saved; assuming an average return between 15 to 36 months one reaches the conclusion that conservation requires investments of US$ 5,250/bpd saved (11).

Conservation of Diesel Oil (6) - The consumption of Diesel oil is distributed in the following way: 75% for transport, 13% for industry and 12% for others. The transport share is distributed between intermunicipal transport (buses and trucks, 55%) and urban transport (mainly buses, 45%).

Possible savings of Diesel oil in the urban areas are intimately related to improvements in the flow of cars, trucks and buses, i.e., reorganization of the traffic rather than technical improvements on the vehicles themselves. This is being done in various degrees around the country but clear success is visible only in the city of Curitiba (Paranã), where exclusive lanes for buses and rescheduling of working shifts have led to economies of 30-40% in fuel consumption.

In road transport, the only significant measure being enacted so far is a shift to heavy Diesel trucks which represents appreciable savings in fuel.

The overall savings of petroleum due to strict conservation measures other than pricing policies of gasoline, fuel oil and Diesel oil are estimated to be 140,000 barrels per day in 1985 relative to the consumption expected in that year without conservation measures (6).

C. The Alcohol Program (the rationale)

In 1975 the brazilian production of alcohol from sugarcane was 903 million liters per year, used mainly for industrial purposes. It was therefore necessary to launch a large program for financing new cultures of sugarcane and associated equipment to increase alcohol production (14,15).

A "deficit" of US$ 8 billion in two years (Table 8) in 1974 and 1975 led the Government to swift action. The prospects for the future in the energy area were considered bleak in 1975 with rising prices of petroleum and there was also a strong preoccupation with the increased dependence on oil from Middle East countries on which little pressure could be applied: as a consequence security of supply became an important consideration.

In addition in 1974 the price of sugar in the international market was very low (approximately US$ 200 per ton). To divert some sugar to alcohol production was considered therefore one method of increasing the value of this commodity and make use of a considerable idle capacity existent in the sugar refineries. Although the price of sugar went up to US$ 608 in 1975 it went down again in 1979 to US$ 120 per ton; one kg of sugar is approximately equivalent to 0.7 liters of alcohol.

Benefiting from government subsidies the program picked up speed and all gasoline used in the country was rapidly converted to "brazilian gasohol" a mixture of up to 20% alcohol and 80% gasoline.

In 1979 with the Irak-Iran war there was a new shock in the expectations of a stable supply of oil from the Middle East and the automobile manufacturers, encouraged by the Government, took the very bold position of producing cars with new motors adapted for pure alcohol consumption. The Alcohol Program entered a new phase from which there was no return.

Brazilian production of alcohol will reach a total of 4.08 billion liters in 1981 out of which 1.88 billions consumed as hydrated alcohol (91-93% alcohol plus water) in more than 300,000 automobiles in addition to the remainder of the fleet which will use 2.2 billion liters of anhydrous alcohol mixed to gasoline at the proportion of 10-20%. The present automobile fleet of Brazil is close to 8 million cars.

Distribution of (hydrated) alcohol benefited from the infrastructure previously used for high octane gasoline; in December 1980 there were 3,587 service stations in the 22 States offering alcohol (in addition to gasohol) which had already replaced all regular gas.

The Executive Committee of the National Alcohol Commission (CENAL) which oversees the implementation of the Program has approved 100 projects with a total capacity of 2.4 billion liters/year, in 1980. As a result, the cumulative number of projects approved so far has reached 321 with a total capacity of 6.4 billion liters/year.

Adding this to the previously existing capacity for alcohol production of 0.9 billion liters in 1975 one has a potential of 7.3 billion liters for projects already approved.

Annex and autonomous distilleries are being installed and over time new capacity has shifted from annex to autonomous distilleries.

The first strategy (annex distilleries) has the advantage of requiring smaller investments and to yield results in a shorter time; the disadvantages are the limited capacity of the industrial units already in place and available land.

The second strategy (autonomous distilleries) offers more freedom but the investments and time for the projects to reach maturity are longer. Both strategies are being followed at the same time in Brazil.

It is estimated that the traditional sector could produce an additional 3.2 billion liters in annex distilleries in a period from 4 to 5 years.

The establishment of new alcohol production centers (autonomous distilleries) could produce another 3.5 billion liters, 3 years after approval by CENAL.

It seems fair to expect that the initial goal set in 1975 of a production of 10.7 billion liters per year in 1985 will be reached, although a 10-20% shortfall in this goal would not be surprising. Out of this amount 9.2 billion liters will be used as fuel and 1.5 billion for other uses in industry.

Many questions have been raised on the real meaning of the Alcohol Program in strict economic terms; is the price of alcohol "real" or "subsidized"; is the Program feeding the already high inflation in Brazil?

What complicates the evaluation of the real cost of ethanol from sugarcane is the complex system of subsidies of the brazilian economy. Initially 90% of the investments (except land) were financed by the Government at very favourable terms (interest of approximately 25%, well below inflation rates of roughly 100%). The Program thus became inflationary although justified by security of supply reasons and the interest in "saving" the automobile industry.

Starting January 1981 financing terms were tightened to conditions which correspond to interest rates of approximately 50% still well below inflation.

Although subsidized, the Program is approaching a situation in which it can be justified in economic terms (16). The cost of production of alcohol from sugarcane is approximately 27 cents/liter i.e. US$ 43,00 per barrel or US$ 58,00 per barrel equivalent to gasoline.This equivalence takes into account the heating values but also the higher efficiency of ethanol in motors(see section IVD). To produce one barrel of gasoline in Brazil(from petroleum at US$35,00 per barrel) costs approximately US$52,00 which indicates that alcohol is rather close to becoming economically competitive.

Questions regarding competition between land uses for food production "versus" fuel production will be discussed in section VIC.

D. The Alcohol Program (technical aspects)

Before 1975 extensive experimentation at the Aerospace Technological Center of the Air Force, in São José dos Campos, demonstrated the technical viability of using Alcohol either in existing or in retrofitted engines.

Figure 6 shows the measured power of Otto engines using either gasoline or ethanol for motors with different compression ratios and of fuel/air mixtures (16,17).

For example, for an Otto engine which had a compression ratio of 6 and was regulated for a 0.08 fuel/air ratio, the resulting power was 9.5 HP (Point A in Figure 6). If ethanol is used in this engine modified for a compression ratio of 10 and using the chemically correct value for the fuel/air ratio (indicated by the line B), the power increases to 12 HP and the specific consumption remains about the same as for gasoline (Point B in Figure 6).

In general the efficiency for Otto engines using ethanol is about 38%, while for gasoline the corresponding efficiency is only about 28%. Engines specially designed for the use of ethanol show a superior "performance".

Automobiles in Brazil use Otto engines with a compression ratio of approximately 6-7 which is suited to the low octane gasoline in use (62 octanes); the use of alcohol, which has 98 octanes, allowed the use of higher compression ratio (approximately 10) and therefore a much better efficiency of the motor. This means that the use of pure alcohol in the US, where the engines have already a higher compression ratio (approximately 9) would not have very spectacular effects.

In practice, although the energy content of alcohol is ~ 60% of the energy content of gasoline, the mileage per liter decreases only 25% when automobiles are converted to the use of hydrated alcohol. Since alcohol is sold at a price up to 65% that of gasoline (per liter) the conversion to alcohol allows a net benefit of ~ 20%.

E. New Initiatives

The success of alcohol produced from sugarcane in substituting gasoline, although rather limited in solving the global energy problem of Brazil, has spurred a number of other approaches to the problem of fossil fuel substitution.

The simple fact that alcohol is a renewable energy source that can be produced domestically has had a very powerful effect on the whole approach of the Government which as a result has come to take far more seriously other initiatives in this area.

Most of these initiatives are geared to find substitutes for Diesel oil,since fuel oil can be replaced by coal or woodfuel with existing technologies.

The most important programs in this area are the use of vegetable oils and methanol (from biomass).

E.1 THE OIL SEEDS PROGRAM The program was established in 1980 and its original goals were to substitute 16% of the Diesel oil by vegetable oils by 1985 and 30% by 1990 (18). For this purpose an additional 1.5 x 10^6 tons of oil for energy purposes will have to be produced in 1985 doubling the normal amount expected in that year for food purposes which is 1.5x10^6 tons. Production of this oil will be based on soya beans and peanuts starting in 1981, colza and sunflower starting in 1982 and palm oil starting in 1986.

The rationale of the Program is to emulate the Alcohol Program and add increasing amounts of oils to Diesel, saving therefore this petroleum derivative. From a strategic point of view this is attractive because of the flexibility in the vegetable oil Diesel mixture. More or less vegetable oil may be added to Diesel depending on the availability of vegetable oil, without the need of irreversible commitments. No changes in existing Diesel motors are contemplated and the new oils would have to be adapted to them. There are three kinds of problems to be solved before such a Program can succeed: technical, agricultural and economic.

From a technical point of view (19) vegetable oils can be mixed with Diesel or used in a pure form but the performance of the motors is affected; not enough long term experiments exist to allow firm recommendations. The situation at present is the following:

a) Diesel motors with precombustion chambers accept either pure vegetable oil or mixtures with Diesel oil. The performance of the motors is very good for some models; in others, carbonization and excessive wear are intolerable.

b) Diesel motors with direct injection do not accept well vegetable oils even if mixed to Diesel oil in low percentages. Most engines in use in Brazil use direct injection.

c) The use of untreated vegetable oils containing glycerol presents problems due to high viscosity, strong odors and undesirable exhaust gases and particulates.

It seems highly advisable to process vegetable oils before using them in Diesel motors; this processing might be less expensive than present processes of preparation of edible oils. This is particularly true in the case of glycerin carrying oils, which most oils under consideration are. In this case a simple chemical process called "<u>trans-sterification</u>" is highly advisable; this process breaks the molecules of "in natura" oils producing hydrocarbonates very similar to Diesel oil with the advantage of permitting the recovery of the glycerin fraction. They could then be used in direct injection Diesel motors.

Questions of cost are still unclear since no large scale

experiments have been conducted. However vegetable oils in the international market are worth at least US$ 500 per ton (close to US$ 700/ton presently), at least twice present Diesel oil costs. In terms of balance of payments considerations it might therefore make more sense to export vegetable oil and import petroleum. However using vegetables oils as a Diesel substitute may still be desirable for supply security reasons.

Oil from some agricultural products might be less expensive than from others and there might also be regional reasons to produce them.

Table 10 gives the characteristics of the oilseeds being considered at present (20). Palm oil seems to be the most interesting option because of its high productivity and lower production costs although it takes at least 5 years to establish extensive new cultures.

A cautious oilseeds program seems very interesting and is being established in Brazil.

E.2 METHANOL (from biomass) Methanol production from natural gas or coal is a well mastered technology and this fuel is favoured in some North European countries as the best replacement for gasoline. Most probably this will not be the route followed in Brazil which already adopted ethanol as the substitute for gasoline. It is unlikely that ethanol and methanol will be both used for automobiles in the near future. The use of ethanol for automobiles and methanol for Diesel motors is the most likely hypotesis until the time when broad fuel tolerance motors are developed.

Burning of pure methanol in present-day Diesel motors can be achieved with small modifications in the motor, mainly the introduction of a glow type spark plug; extensive testing of this solution is taking place with encouraging results. In addition to that, use of methanol in stationary motors in locomotives or industry offers great opportunities.

For this reason an experimental program has been established by CESP (Energy Company of the State of São Paulo) to produce methanol from eucalyptus in some areas of Southeast

Brazil (21).

This idea requires setting up gasifiers for the production of synthesis gas from biomass; once obtained, the synthesis gas can be converted to methanol by existing technologies.

Three large size (200 dry tons of wood/day) gasifiers of different types are being installed to test technologies which have only been tested in laboratory scale: one of the gasifiers uses a fluidized bed at atmospheric pressure, another one a fluidized bed at high pressure and a third one a newly developed electric arc gasifier. Results should be available within two years.

The cost of methanol should be quite low as compared to ethanol from sugarcane although initial investments are higher.

E.3 ETHANOL PLUS ADDITIVES (22) Since the Alcohol Program (ethanol) seems well entrenched in Brazil, a number of experiments have been made to use it in Diesel motors; in order to do that it is necessary to add an explosive to it such as hexile nitrate (in the amount of 12%) or trietileneglicol (in the amount of 4 to 5%). Very good results have been reported with these fuels, although questions of price remain to be solved.

The idea of using a mixture of Diesel oil and pure alcohol in dual injection engines is also being investigated.

E.4 ETHANOL FROM WOOD (23) In addition to ethanol produced from sugarcane, it will probably be produced in the future from wood through the acid hydrolysis method; the use of wood will allow the use of marginal lands through reforestation.

A state owned company named COALBRA was established by the Government in 1980 to build and operate the first pioneer plants based on this technology. The first one, a 30,000 liters/day plant is being installed in Uberlandia, Minas Gerais and should begin operating at the end of 1982. The main characteristics of this plant are the following:

Hydrolysis of eucaliptus will be performed by a modified version of the Madison-Schoeller process: diluted sulphuric acid separates the lignin and saccharifies the celulose portion of the wood leading to a fermented wine containing - 1,5% of ethanol. This wine is distiled producing pure ethanol; as by-products one obtains CO_2, proteins and lignin which can lead to coke after briqueting and carbonization.

Expected yields per ton of dry wood are the following:

Ethanol	- 160 liters
Proteins (from the pentoses)	- 75 kg
Furfural	- 9,5 kg
CO_2	- 96 kg
Lignin	- 338 kg (or 135 of coke)

Investments for this plant are estimated to be approximately 15 million dollars and the final price of the alcohol approximately US$ 0,30/liter.

E.5 WOODFUEL; CHARCOAL AND BAGASSE Wood has been the dominant fuel in Brazil until 1954 and its use has remained approximately constant since then although, in relative terms, it's contribution has been decreasing rapidly. Consumption in 1979 was $20{,}5 \times 10^3$ TEP or $87{,}5 \times 10^3$ tons (220×10^6 m^3 of wood with 10% humidity).

On this matter an interesting methodological question was raised by Brown (24) which analized the calorific content of wood as defined in Brazil. Brown pointed out that the calorific content used in the government documents (1) was calculated with an error due to the fact that the density of wood is quite different when dry or wet. When dry, the density of wood is $0{,}4$ ton/m^3 and when wet (with 25% humidity) is $0{,}53$ ton/m^3. Also the calorific content for wet wood (2,5Mcal/ton) and not for dry wood should be used.

The effect of correcting for these errors is an increase of the amount of energy per ton of wood of 35%. The real amount of energy in TEP coming from fuelwood should therefore be increased from

$20,469 \times 10^3$ TEP (consumption in 1979) to approximately $27,000 \times 10^3$ TEP

A breakdown of uses of wood as an energy source (24) is given in Table 11.

Charcoal consumption in 1979 was $2,976 \times 10^3$ TEP which corresponds to $16,700 \times 10^3$ m^3; charcoal is an important ingredient in the preparation of pig iron in Brazil. About 40% of the steel production of Brazil uses charcoal instead of imported coke (25).

Traditionally charcoal has been produced by the conversion of natural forests which has contributed to deforestation in many areas, specially in the State of Minas Gerais; in addition to the environmental effects this has led to scarcities in the supply of woodfuel and increases in price since woodfuel and charcoal have to be transported from longer distances.

As a consequence the Government has encouraged reforestation projects through subsidies; in the period 1965-1980 approximately 3 million ha of land were occupied by reforestation projects using pinus and eucalyptus both of which grow rapidly in the favourable climate of Brazil; yields of wood which correspond to 6-8 ton/ha/year or higher are commonplace. Not all reforestation projects are destined to charcoal but to other energy uses of fuelwood, pulp and the paper industry.

The energy conversion efficiency from wood to charcoal is approximately 40-50% on using primitive methods; this efficiency can be raised, a) by improvements in basic kiln type, at low cost to ~ 60% and b) to 65-70% by recovery of tars with the same kiln type.

Enormous quantities of bagasse will result from the large Alcohol Program which is based on sugar cane. As is well known even if all energy needs of the alcohol distilleries were run on bagasse as a source of heat, a large surplus would be still available. The production of 1 liter of alcohol produces approximately 2 kg of dry bagasse, of which only 1 kg is needed in the process in the form of heat and electricity if modern technologies are used in the processing plant.

Cogeneration schemes could be used to produce electricity (in addition to the heat needed for industrial purposes in the distilleries) and the excess sold to outside consumers(26). Government regulations have been changed recently to allow that.

F. The Food "versus" Fuel Controversy

Considering the size of Brazil and the possibilities of expansion of the agricultural frontier is it possible in the long run to produce all the alcohol needed for fuel in addition to the land needed for food production?

In the short run, fuel production will have to be done at the expense of other agricultural products, unless the agricultural frontier is expanded (27). Out of the 45.9 million hectares of agricultural land in use in Brazil in 1977, approximately 60% were used for products for domestic consumption (rice, blackbeans, cassava, corn, onions, tomatoes, etc.), 38% for exports (cotton, soyabeans, sugar, coffee, etc.) and only 2% for fuel.

The share of land needed for fuel purposes (including oilseeds for substitution of Diesel) will increase to 7,3 million hectares in 1985 (4,3 million ha for sugarcane, 1,8 for energy forests and 1,2 for oilseeds); the present amount of land covered by sugarcane for alcohol purposes is 1 million ha. In the last 40 years land for all agricultural uses has been growing at a rate of 3,5%. Future used land areas will have to grow faster than that (Table 12).

Significant expansions of the agricultural frontier have occurred in short spans of time in Brazil in the recent past; this is the case of soyabeans which became, in a matter of few years, the dominant export crop using presently 8,7 million of ha of land.

Although the rate of growth of land needed for fuel production is quite high, the absolute amount of land is not and steps are being taken by a number of private groups to produce crops for fuel in regions which are not being used at present for productive purposes. This is the case of many developments in Bahia, Mato Grosso do Sul and Goiás.

However, in some regions of the country, such as São Paulo, incentives for sugarcane production are displacing rapidly other crops. To compensate for that, marginal land can be recovered. This seems to correspond therefore to a regional problem.It is unclear however, at this time, the real effect of crop displacement on prices of agricultural products.

To keep things in perspective one should realize that the agricultural area of the United States is 20,5% of its total and only corn covers 3,1% of the total area ($28{,}315\times10^3$ ha in 1978). The idea that sugarcane plantations will convert Brazil into a monoculture and lead to an ecological disaster seems unwarranted in the light of the present situation in the U.S.A.

G. Nuclear Energy (14,28)

Large scale use of nuclear energy in Brazil is a very controversial subject: a 624 Mw pressurized water reactor(PWR) was purchased in 1969 from Westinghouse after a long period of hesitation. In this reactor fueled with enriched uranium, no significant transfer of technology was contemplated; participation of Brazilian industry was restricted to the civil works and some low technology equipment. The decision to purchase this reactor was strongly criticized, for these reasons, by many scientists and by industry spokesman.

In the fifties many Brazilians were trained in nuclear technology and Brazil was one of first developing countries to receive a research reactor (5 Mw) under the "Atoms for Peace" program; considerable interest developed in the use of nuclear energy both as a source of energy and as a frontier technology which could spur developments in other areas such as metalurgy, electronics, etc. At the time strong similarities existed between the type of nuclear program developed by India and Brazil: among scientists a strong feeling developed that nuclear power should result in the complete domain of the technology involving all phases of the construction and operation of the reactors.

Sensitive to that criticism, the government in 1974 embarked on an ambitious nuclear program in cooperation with West Germany which in principle would lead Brazil to complete autonomy in the nuclear field within a period of 15 years(14).

Eight PWR's (1300 Mw each) were scheduled to be installed in Brazil with an increasing index of nationalization that should come close to 100 percent in 1990. A semi-industrial uranium enrichment plant was to be built in Brazil based on the "jet-nozzle" method. In addition a spent fuel reprocessing plant was to be built by German enterprises. In all cases joint companies were to be formed. This program was defined as being the minimum capable of justifying the setting up in Brazil of all phases of the nuclear industry, including the complete fuel cycle (mining, enrichment and reprocessing) and the construction of the nuclear reactors themselves. Technology transfer was included as an ingredient of the Program.

Although there was some initial enthusiasm for such a comprehensive nuclear program, the difficulties soon became apparent.

First, the feasibility of uranium enrichment (which is essential if any real autonomy is to be achieved was viewed with strong skepticism by many scientists because the Becker "jet-nozzle" method to be used has not been considered a proven method; for many years to come, therefore, enriched uranium would have had to be purchased from other suppliers frustrating the dreams of "nuclear independence".

Second, the transfer of technology was not successful from the very start; with disagreements on the role to be played by Brazilian local industry and German industries it became apparent that the program was heavily biased in favour of the German suppliers.

Third, the role of Brazilian scientists and technological institutes was neither properly defined nor given much attention which strengthend suspicions that no real transfer of technology would occur.

Finally, the planned installation of a spent fuel reprocessing plant raised strong objections in the United States because such a plant would constitute an added danger to nuclear proliferation.

In addition to these issues, the question of whether there is a real need of nuclear power in a country such as Brazil, well endowed with hydroelectric resources, was raised . Reassessment of hydroelectric resources made by Eletrobras, the state enterprise for electricity, has almost doubled the known potential since 1974 (29).

The question of the economics of nuclear power furthermore has became an important one. In 1974 nuclear power was seem as a cheap source of energy. By contrast, today, dramatic cost increases have cast the economics of nuclear power in doubt, more so in LDC's than in developed countries.

As a consequence of these facts and gross mismanagements in implementation, a reassessment of the program is presently underway: out of the eight reactors scheduled for operation in 1990 only 2 will be operating in the most optimistic hypothesis. It is expected that the remaining six reactors will not operate until the year 2000 postponing to the distant future all the questions raised above on enrichment and reprocessing.

Most Brazilian scientists and industrialists would probably prefer a more modest program in which they could play a dominant role and acquire progressively the necessary technology.

V. ENERGY PROJECTIONS

Most of the investments in infrastructure in Brazil are made by State owned enterprises which have a monopoly in given sectors of the economy such as Petrobras for petroleum, Eletrobras for electricity, Nuclebras for nuclear energy, etc. For this the reason it is possible to formulate goals for the full presidential period such as the present one which lasts until 1985 (Table 13). These goals are given in the "Brazilian Energy Model" of the Ministry of Mines and Energy (30).

Plans have been made for important expansions in the industrial sectors which will drive energy needs at the above mentioned rates.

In the period 1969/1979 the GDP of Brazil has increased 8,9%/year and it is expected that it will continue to grow at a rate between 6 and 7% in the period 1979/1985.

The hydroelectricity consumption is expected to grow at even higher rates: 12.0% in the period 1979/1985; 8.2% in the period 1985/1990 and 7.4% in the period 1990/1995. The electric sector is the only one in which projections are made with a 15 year lead time.

The assumptions and rationale behind the MODEL above are interesting to probe and we will do that in what follows. Being an official Government document it contains some elements of propaganda and wishful thinking but it incorporates the better structured programs such as the Alcohol Program, which represents the most successful attempt to replace petroleum derivatives, and the Hydroelectric Program.

A. Petroleum and Natural Gas

The goals of the present program of internal petroleum production are to reach 500,000 bpd, up from the 170,000 bpd produced in 1979. The important new discoveries made in the Campos basin in 1976 are already producing minor amounts of oil but should reach full production before 1985.

The 500,000 bpd in 1985 are to be reached in the following way: 231,000 bpd - production from wells presently in operation; 127,000 bpd - production from wells due to operate in the next few years; and 142,000 bpd - production from newly discovered wells.

These are quite speculative goals; presently existing wells, mainly in Bahia, are operating at full capacity and it is doubtful if their production can be increased without seriously compromising future extraction. The Campos basin which was the reason for great enthusiasm a few years ago, when it was discovered, has developed a number of problems and its production -- around 30,000 bpd in 1980 -- is well below expectations. Finally to count on production from "newly discovered wells" is a rather dubious proposition.

The desire of the Government to increase oil production has been considerable and therefore it changed in 1977 existing regulations allowing foreign oil companies to prospect on the Brazilian continental shelf under "risk contracts".

This was a very hotly debated decision and it took a lot of determination from the Government to take it in the face of criticism of the more nationalistic currents of the Army and Petrobras; the fact that it was taken shows the seriousness of the oil situation and the influence of foreign capital in Brazil. The presence of a number of foreign companies in exploration of oil has however proven so far to be very disappointing.

Natural gas is always associated with petroleum in Brazil and has not been used very widely for energy purposes: in 1979 total use was 498x10^3 TEP (547x10^6 m^3); in addition, an unspecified amount has been used for reinjection in wells and as raw material for the production of fertilizers and petrochemical industry in the State of Bahia.

Projections for consumption in 1985 in well defined uses, are presently 1,186x10^3 TEP (1,303x10^6 m^3).

B. Coal

Coal traditionally represented a small contribution to the energy profile of Brazil never amounting to more than 5% of the total primary energy consumed.

In 1979, consumption was 8,606x10^3 tons of which 4,252x10^3 tons imported (mostly metalurgical coke) and 4,414x10^3 tons produced domestically(mostly for non-metalurgical purposes such as steam production, due to the high content of ashes in the brazilian coal).

The projections for coal consumption in 1985 reflect the evolution of pig iron production in the Government plans. In addition , coal for steam production will become more important because it will be used as a substitute for fuel oil in many industries (mainly cement, ceramics, paper and pulp, etc.). One expects therefore for 1985 almost a tripling of the imports of the metalurgical coke and an increase by a factor of 5 for the production of local coal which should reach 27,5x10^6 tons in 1985.

In the beginning of 1981 this goal was already reduced to 17 million tons.

C. Shale

The only project for the production of oil from shale presently underway is being conducted by Petrobras in São Mateus do Sul, Paraná, where some of the most important shale reserves are located; this is a 50,000 bpd plant to be built with technology developed in Brazil and already tested in a 5,000 bpd pilot plant in the same location (5). Environmental problems associated with such plant have yet to be solved, mainly the ones associated with the disposal of the huge quantities of rock removed from the soil which remain after the removal of the oil from the rock shale. The first stage of the plant

(25,000 bpd) is to be completed in 1984 and the second one (50,000 bpd) in 1986. In full operation 900 tons of sulphur and 400 tons of LPG(liquefied petroleum gas)will also be obtained as by-products.

D. Hydro

In 1979, only 12.5% of the measured hydroelectric potential was in use; the average growth in the 1979/1985 period expected to be 14.2%/year reaching 227.566 Gwh in 1985, or 24.4% of the existing potential although many believe that such high rates of growth will not be maintained. Most of the activities leading to the production of this amount of electricity are underway: the first stage of the great hydropower station of Itaipu (final capacity 12,000Mw) will be producing electricity in 1983 which will be transported to São Paulo through two transmission lines, one AC and another DC.The latter represents a newly introduced technology in Brazil which will be very important for the future utilization of the large hydropotentials of the Amazonas basin. In addition, Tucuruí (4,500 Mw), first large hydropower station in the Amazonas basin, will start operation as well as Foz de Areia and Salto Santiago in the Southern region.

An important priority of Eletrobras is the interconnection of the North and Northeast regions.

E. Nuclear Energy

The most obvious progress made in this area in recent years is the increase in the uranium reserves (215,300 tons of U_3O_8 in 1980). Production of yellow cake is due to start in 1981 in the Poços de Caldas plant with 150 tons/year which will increase to 1,100 tons/year in 1985. The only nuclear power plant in operation in 1985 will be a 624 Mw reactor purchased from Westinghouse in a "turn key" basis; it should begin operation in late 1981, and will initially be fueled with imported enriched uranium; the refueling will be made with locally produced U_3O_8 which will have to be enriched abroad. The rest of the ambitious nuclear program is seriously delayed.

F. Biomass

F.1 WOODFUEL Since Brazil is going through a process of rapid urbanization the consumption of wood for domestic purposes (mainly cooking) has been declining, being replaced by LPG and electricity. To compensate for that the substitution of fuel oil has increased wood consumption for industrial purposes. Projections for consumption in 1985 are 82,359x10^3 tons slightly below the consumption level in 1979.

F.2 CHARCOAL A projection of the needs of the steel industry indicates that charcoal production should increase to 9,115x10^3 TEP (14,492x10^3 tons) in 1985, a three fold increase from production in 1979. Approximately one million hectares of reforested areas will be needed for that, generating 47,000 direct jobs (4,7 jobs/100 ha).

F.3 BAGASSE If the goal of 10,7 billion liters/year of the Program is reached by 1985 there will be a surplus of 10,700x10^3 ton of bagasse in addition to the bagasse obtained from sugar production.

Consumption of bagasse was 5,489x10^3 TEP in 1979 and the projection to 1985 is 9,646x10^3 TEP (46,154x10^3 tons of bagasse with 50% humidity).

G. Solar

A very small amount of solar units are in use in Brazil presently; projections for 1985 are such that 0,43% of the total energy used at that time will come from solar devices; this corresponds to 15,000 bpd (1,000 from solar direct and eolics, 4,000 from biogas and 10,000 from other forms).

An independent assessment (31) indicates that residential water heating, water preheating in industry, agricultural drying and water distillation are the main opportunities for solar direct energy and irrigation for wind.

The results are shown in Table 14.

Roughly speaking 1,400 to $2,500\times10^3$ TEP of energy could be generated from solar and wind energy. This corresponds to 1,2% to 2,1% of all energy consumed in the country in 1979.

H. Overview of Projections

We have assembled in Table 15 the figures for energy consumption projected for 1985 according to government goals (1,6, 30). In this Table all numbers were converted to barrels equivalent of petroleum per day (BEP/day); to obtain consumption in TEP/year it is necessary to divide the numbers by 20.5.

In the same Table are given the numbers for the energy consumption in 1979 and the increments in energy consumption expected in the period 1979-1985.

Also included are figures for conservation taken from Section IV B.

The investments needed to reach these goals have been estimated (32) and are given in Table 16. The availability of capital for such high investments does not seem very realistic at present.

VI. SOCIAL ISSUES

It is implicit in the Government projections that no important changes in the social "status quo" will occur in the near future and therefore no changes in the structural composition of energy consumption. The maximum one can expect is conservation and substitution of some fuels by others.

A comprehensive discussion of the energy needs of a country cannot ignore however who consumes,how income is distributed and related social questions such as land use and ownership. We will tackle these questions in what follows.

A. The Structure of Energy Expenditures (33,34)

The income distribution in Brazil is very asymetric with most of the income concentrated in the hands of 10-20% of the population. This can be seen clearly in Figure 7 which shows in detail the income distribution of the population of the State of São Paulo, which is the wealthiest of the country.

It is obvious that presently, rural and urban non-metropolitan areas have more poor people than rich people in relative terms than metropolitan areas and consequently they consume less energy per person.

Surveys of monetary and non-monetary expenditures of households with different incomes are available.Figure 8 shows, for the year 1970,calculated energy expenditures associated with these expenditures, grouped into four brackets: 0-2, 2-5, 5-10 and more than 10 minimum monthly wage units.(One wage unit corresponds to approximately US$41 in 1970).Total energy consumption in the highest income group is fifteen times greater than in the lowest income group; 66% of the population is in this low income group while 4% is in the highest income group, which is responsible for one quarter of the total energy consumption of the country (mostly petroleum products). Low income groups consume less petroleum products (38%) than higher income groups where petroleum products account for 66% of the total.

The structure of energy expenditures consumption for the whole country in 1970 is the following: food(27.0%) , transportation (19.3%), household (11.5%), civil construction (15.7%), distribution (5.0%) and others (21.5%) indicating that food production consumes as much energy as the transport sector.

B. Urban "versus" Rural Energy Consumption

The low energy consumption "per capita" in rural areas of India (35) is frequently quoted to indicate that there is a large increase in energy consumption associated with urbanization.

A detailed study of this question in rural, urban non-metropolitan and metropolitan areas in the State of São Paulo, Brazil (36) leads to the conclusion that the primary energy consumption "per capita" is solely determined by income:the low primary energy consumption of the rural areas merely reflects the fact that the personal income of people in those areas is very low.

The results of this work are shown in Figure 9 which gives the direct and total (direct plus indirect) energy expenses for the three areas mentioned above.

This is a very important and somewhat surprising result; although presently there are few rural households with large incomes in Brazil, it seems to be inescapable that they will fall in the general pattern of consumption of urban areas as their income increases, incorporating in the process more energy efficient systems.

If one multiplies the distribution of population as a function of income as given in Figure 7 by the primary energy consumption as a function of income (Figure 9) one obtains the total energy consumption as a function of income. The area under this curve is the total energy consumed by the population (approximately 116×10^{15}cal).

It is interesting to notice that if a very severe redistribution of income were to take place, as indicated by the dotted line in Figure 7, the energy consumption of the population would correspond to a total energy consumption of 135×10^{15}cal. This means an increase in primary energy consumption of 15% which indicates that the total energy requirements of society would not be very different from present ones. Redistribution of income would not lead to an inordinate increase in primary energy consumption; the reason for that is that most of the additional income would go for food and direct energy expenses and not for automobiles and other extravagant methods of spending energy.

Most of this increase will be done however in petroleum derivatives with a consequent decrease in fuelwood consumption.

This result is somewhat surprising and runs counter to "conventional wisdom" which indicates that a distribution of income would lead to a large increase in the purchase of energy intensive goods and therefore to a further worsening of the energy crisis.

C. Patterns of Land Utilization (37)

As a result of the Alcohol Program large sugarcane plantations are being established in regions where previously many small farms existed; this is favoured by the fact that sugarcane production is well suited to mechanized techniques and by government policies. As a consequence, the subsistence crops which existed in the small farms (corn, vegetable, blackbeans, etc.) are being eradicated forcing the importation of food from faraway regions.

This had the very negative social consequence of forcing the exodus of small farmers and labourers in the fields to small cities where it is difficult to get jobs. They become therefore seasonal labourers for the large plantations, since sugarcane is a 6-months per year activity.

The use of large farms fostered for technical reasons and the availability of government subsidized credits for alcohol production has generated a few very large companies that hold most of the land in many regions of Brazil. This has had a negative effect on the income distribution, concentrating resources in the hands of a few privileged enterpreneurs. This is clearly a consequence of the policies followed by the government and could have been otherwise. A system of cooperatives in which individual farmers could grow sugarcane and process it in a collectively owned refinery is possible and is the method used in Australia: this however has not been the case in Brazil.

VII CONCLUSIONS

The stage of development reached by Brazil is typical of a number of developing countries; the lack of abundant fossil fuels, the abundance of land and forests, a highly developed urban sector, a very skewed income distribution and a mounting external debt are common characteristics of many Latin-American and some African and Southeast Asia countries.

The emphasis put on the use of biomass as an energy source - mainly through the production of ethanol - is however unique to Brazil. This strategy can be adopted in a number of other countries (37). The production of large quantities of ethanol from sugarcane is possible in India, Cuba, China, Mexico and Pakistan; the use of forests for the production of charcoal, methanol or ethanol is very promising in Indonesia, China, Zaire, Austrália and Colombia.

It has been estimated (38) that the present participation of biomass in the energy budget of all developing countries which was 4.4% of the world's energy consumption in 1976 could be increased to 11% by 1995 (1,550 million tons of coal equivalent).

This amount of renewable energy would correspond to a very important fraction of the energy consumed in developing countries.

One has therefore in many countries the possibility of a sustained development based on locally produced modern liquid fuels derived from biomass avoiding the undesirable dependence on the use of imported fossil fuels.

The unique experience with biomass in Brazil teaches also that one should attempt its utilization with less advence environmental and socioeconomic impacts.

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Literature Cited

1. Balanço Energético Nacional. 1980. Ministério de Minas e Energia, Brasilia. 104 pp.
2. Exploração e Produção de Petróleo no Brasil. 1980. Cadernos Petrobrás 3. 80 pp.
3. Hubbert, M. K. 1979. US Energy Resources, a Review as of 1972. Committee on Interior and Insular Affairs, US Senate 93d Congress 2d Session. US Government Printing Office, Washington DC. 199 pp.
4. Lara, S. B. 1980. Avaliação Global do Carvão Mineral Nacional. Atualidades do Conselho Nacional do Petróleo 72, pp. 8-18.
5. Moreira, H. B. 1981. Xisto - Contribuição para complementação da produção de petróleo. Atualidades do Conselho Nacional do Petróleo 73, pp. 41-69.
6. Magalhães, C. A. 1981. Modelo Energético Brasileiro - Encontro sobre o Estudo do Balanço Energético em seus Aspectos Físicos e Econômicos. Itaipava, Rio de Janeiro. 51 pp.
7. Carvalho, H. G. 1979. O Programa Nuclear Brasileiro. Conferência pronunciada na Comissão de Ciência e Tecnologia da Câmara dos Deputados. Brasilia. 32 pp.
8. 1978 FAO Production Yearbook. 1979. Food and Agricultural Organization (FAO) of the United Nations. Italy, Rome. vol. 32.
9. Wilberg, J. A. 1974. Consumo Brasileiro de Energia. Energia Elétrica 27. pp. 17-29.
10. Conjuntura Econômica. 1981. Vol. 35, pp. 31.
11. A Crise dos Combustíveis Líquidos. 1980. Confederação Nacional da Indústria. Vol. I, 59 pp.
12. Constanza, R. 1980. Embodied Energy and Economic Variation. Science 210:1219-1224.

13. Moreira, J. R., Goldemberg, J. 1981. Preço de Energia no Brasil e Estados Unidos. 33a. Reunião Anual da Sociedade Brasileira para o Progresso da Ciência. Salvador, Agosto 1981.

14. Goldemberg, J. 1978. Brazil - Energy options and current outlook. Science 200:158-164.

15. Garnero, M. 1981. Alcohol fuels in Brazil. Testimony presented in the sub-committee on Energy, Nuclear Proliferation and Government Affairs. US Senate, March 24. 22 pp.

16. Moreira, J. R., Goldemberg, J. 1980. Alcohols - its use, energy and economics. Institute of Physics, University of São Paulo. Preprint IFUSP/P-230.

17. Stumpf, U. E. 1977. Aspectos técnicos de motores a Alcool. 29a. Reunião Anual da Sociedade Brasileira para o Progresso da Ciência. São Paulo, 1977.

18. Licio, A. A. 1980. O óleo vegetal como matéria prima. Energia 11:15-18.

19. Aguiar, A. C. S. 1980. Análise e conclusões do I Encontro sobre Tecnologia de Óleos Vegetais Combustíveis. Energia 11: 89-95.

20. Accioli, J. L., Alvim, C. F., Afioni, M. E., Rodrigues, J. F. A. 1981. Oleos vegetais. Secretaria de Tecnologia Industrial. Brasilia. 50 pp.

21. Oliveira, E. S. 1980. The Electro Chemical Route Wood to Syngas. Proceedings of the IV International Symposium on Alcohol Fuels Technology. vol. I. Guarujá. pp. 199-204.

22. O álcool aditivado em substituição ao óleo Diesel. 1980. Energia 8:13-47.

23. COALBRA - Coque e Alcool da Madeira S.A. 1980. Programa Nacional da Produção de Etanol a partir da Madeira. Sumário do Estudo Básico. Brasilia.

24. Brown, R. I. 1980. O consumo de madeira no Brasil. Institute of Physics, University of São Paulo. Preprint IFUSP/P-22. 70 pp.

25. Diretrizes para o Problema do Carvão Vegetal na Siderurgia. 1973. Ministério da Agricultura IBDF. Boletim Técnico nº 3. 102 pp.

26. Moreira, J. R., Goldemberg, J., Serra, G. E. 1979. A cogeneration scheme for the production of alcohol and electricity from sugarcane. Institute of Physics, University of São Paulo, Preprint IFUSP/P-13.

27. Mello, F. 1981. Implicações alocativas e distributivas do Programa Energético. FIPE São Paulo. 64 pp.

28. Krugmann, H. 1981. The Bulletin of the Atomic Scientists 37:32-36.

29. Eletrobrás - Centrais Elétricas Brasileiras S.A. Set. 1979. Plano de atendimento aos requisitos de energia elétrica até 1995. Rio de Janeiro, Brazil.

30. Modelo Energético Brasileiro. 1981. Ministério de Minas e Energia, Brasilia. Versão II. 91 pp.

31. Goldemberg, J. 1980. Role of Solar Energy in Brazil. Report for the World Bank. Institute of Physics, University of São Paulo. 34 pp.

32. Mattar, H. 1980. Programa Energético Nacional: possibilidades e impactos. Seminários "Energia e Desenvolvimento" CENDEC-IPEA. Brasilia. 52 pp.

33. Graça, G. M. G., Gebara, N., Goldemberg, J. 1981. Usos de Energia no Brasil (1970). Institute of Physics, University of São Paulo. Preprint IFUSP/P-262. 24 pp.

34. Vanin, V. R., Graça, G. M. G., Goldemberg, J. 1981. Padrões de Consumo de Energia no Brasil (1970). Ciência e Cultura 33, 477-486.

35. Revelle, R. 1976. Energy in rural India. Science 192:969-975.

36. Vanin, V. R., Graça, G. M. G., Higa, T. T., Droichi, M. S., Goldemberg, J. 1981. A note on the energy consumption of urban slums and rural areas in Brazil. Institute of Physics, University of São Paulo, Preprint IFUSP/P-236.

37. Goldemberg, J. 1980. A centralized "soft" energy path. International Energy Symposia Series - Sumposium I. Knoxville, Tennessee.

38. Moreira, J. R., Goldemberg, J. Solving the Energy Problem in Latin America. International Conference on Energy Use and Management-III. Berlin, Oct. 26-30 1981.

Figure Legends

Figure 1 - Oil findings (in barrels/meter drilled) for each million of meters drilled in Brazil.

Figure 2 - Evolution of the primary energy consumption profile from 1940-1980 in Brazil.

Figure 3 - Evolution of prices of petroleum by-products relative to 1970 (in constant currency).

Figure 4 - Evolution of the automobile and truck fleets (left side scale) and fuel consumption (right side scale). Also shown the projected consumption of alcohol (ethanol) up to 1985.

Figure 5 - Frequency plots of embodied energy (in kcal/cruzeiro) by sector for the USA (1961 data base) and Brazil (1970 data base); cruzeiro is the brazilian currency unit (one 1970 US dollar = 4.59 cruzeiros).

Figure 6 - Engine power "versus" fuel to air mixture for regular low octane gasoline and anhydrous alcohol. A-chemically correct mixture for gasoline; B-chemically correct mixture for ethanol.

Figure 7 - Household expenditures in the State of São Paulo in 1974 as a function of the income (in wage units-WU). One WU corresponds to US$ 52 (november 1974).

Figure 8 - Distribution of the number of families and total daily energy consumption per family for different incomes in Brazil in 1970. One wage unit (WU) corresponded to approximately US$ 41 in 1970.

Figure 9 - Energy expenditures (direct and total) for metropolitan, urban non-metropolitan and rural areas of the State of São Paulo (Brazil) in 1974 as a function of household expenditures. 1 WU ≅ US$ 52 (november 1974).

Table 1 Energy resources in Brazil (Dec. 1979)

Source	Unit	Resources[a] Measured	 Estimated and Infered	 Total
FOSSIL FUELS				
Petroleum	$x10^6$ m^3	198	-	198
Natural gas	$x10^9$ m^3	47	-	47
Coal	$x10^6$ ton	4,836	17,938	22,734
Shale oil	$x10^6$ m^3	465	207	672
Nuclear[b]	ton of U_3O_8	126,000	89,300	215,300
RENEWABLE SOURCES				
Hydro[c]	Gw	67,0	39,5	106,5
Biomass[d]	$x10^6$ tons/year	-	-	200

[a] For fossil fuels the total resources are given; for renewable sources the energy available per year on a continuing basis.

[b] At costs not higher than US$ 95/kg.

[c] To electricity is attributed the calorific content of oil needed to produce electricity with an efficiency of 27.5%: 1 kwh = 3150 kcal (1 Mwh = 0,29 TEP).

[d] Estimated on the basis of 10 tons of dry biomass fuel per hectare/year.

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1 ton = 1000 kg.
1 Mw = 10^3 kw = 10^6 w
TEP = ton of petroleum equivalent

Table 2 Coal reserves in (10^6 tons) (1979)

State	Measured	Indicated	Infered
Rio Grande do Sul	947.5	2,597.8	9,397.9
Santa Catarina	369.3	859.0	712.8
Paraná	32.0	27.7	5.0
São Paulo	2.0	1.0	7.0
Total	1,350.8	3,485.5	10,122.7

1 ton = 1000 kg.

Table 3 Shale oil reserves (1980)

State	Area (km^2)	Average oil content (%)	Total resources in oil ($x10^6$ barrels) Measured and infered
São Paulo (Vale do Paraîba)	191	4	2204[a]
Paranã (São Mateus do Sul)	64.5	7.4	560
Rio Grande do Sul (São Gabriel)	84.0	7.0	240
Rio Grande do Sul (Upacarai)	191.0	6.8	463

[a] 60% of this amount corresponds to infered resources.

Table 4 Hydroelectric resources (1980)
(Gigawatts of installed or installable capacity)

Region	In use or in Construction	Still available (measured)[a]	Still available (estimated)[b]	Total
North	4.073	40.697	53.023	97.793
Northeast	8.217	6.011	1.194	15.422
Southeast	25.095	18.012	13.518	56.625
South	13.400	16.495	13.640	42.935
Total	50.705	81.215	81.375	213.375

[a] Based on topographical surveying in the prospective sites and minimal flows in the last 40 years.

[b] Estimates based in aerophotogrametric surveys and minimal flows in the last 40 years.

Table 5 Uranium reserves (tons)

Year	Measured and indicated	Infered	Total
1970	700	-	700
1971	1,730	3,300	5,030
1972	3,080	3,000	6,080
1973	3,580	4,500	8,080
1974	3,940	7,100	11,040
1975	3,940	7,100	11,040
1976	16,900	9,480	26,380
1977	32,300	34,500	66,800
1978	-	-	-
1979	126,000	89,300	215,300

Table 6 Land utilization in Brazil (1977)
($x10^3$ hectares)

Total area[a]	851,197
Land area [b]	845,651
Arable land and permanent crop[c]	40,720
Permanent meadows and pastures[d]	166,000
Forest and woodland[e]	509,000
Other land[f]	129,931

[a] Total area refers to the total area of the country, including area under inland water bodies.

[b] Land area refers to total area excluding area under inland water bodies, i.e., lakes and rivers.

[c] Arable land refers to land under temporary crops (double cropped areas are counted only once); permanent crops include crops which take more than 5 years, e.g., tea and coffee.

[d] Permanent meadows and pastures refers to land used permanently for herbaceous forage crops, either cultivated or growing-wild.

[e] Forest and woodland refers to land under planted and natural forest and bushes.

[f] Other land refers to unused but potentially productive land built on areas, waste land, parks, roads, lanes, etc.

Table 7 Primary energy consumed (1979)

Energy source	$x10^3$ TEP	%	Average yearly rate of growth 1969-1979 (%)
Oil	47,974	40.7	8.3%
Gas	498	0.4	17.9%
Alcohol	1,876	1.6	52.8%
Hydro	33,379	28.3	13.4%
Coal	5,123	4.3	8.1%
Bagasse	5,489	4.7	8.1%
Charcoal	2,976	2.6	9.6%
Woodfuel	20,469	17.4	0.7%
Total	117,785	100.0	7.7%

Table 8 Petroleum imports and balance of payments (1971-1980)
(billions of dollars)

Year	Exports	Imports	Balance	External debt Accumulated	Petroleum imports	Petroleum imports (Share of total exports)
1971	2.904	- 3.245	0.341		280	9.6%
1972	3.991	- 4.235	- 0.244	9.521	376	9.4%
1973	6.199	- 6.192	+ 0.007	12.571	718	11.7%
1974	7.951	-12.641	- 4.690	17.165	2.812	35.2%
1975	8.670	-12.210	- 3.589	21.171	2.747	31.6%
1976	10.130	-12.277	- 2.147	25.985	3.460	34.0%
1977	12.120	-12.024	+ 0.006	32.837	3.664	30.1%
1978	12.659	-13.683	- 1.024	43.510	4.089	32.3%
1979	15.244	-17.961	- 2.717	49.904	6.189	40.5%
1980[a]	20.132	23.100	- 2.868	-	10.300	51.2%

[a] Estimated

Table 9 Prices of Petroleum derivatives (April 1981)
US$/liter

Derivative	Brazil	US	France
Gasoline	0,81	0,30	0,63
Diesel oil	0,39	0,21	0,50

Table 10 Vegetable oils in Brazil

Source	Productivity (Tons/hectare/year)	Fraction of oil %	Amount of oil (kg/hectare)
Palm	20 - 25	17 - 20	3,400 - 5,000
Coconut	23 - 29	5 - 7	1,115 - 2,100
Babaçu	2,0 - 3,0	3 - 4	60 - 120
Sunflower	1,8 - 2,5	30 - 55	480 - 1,375
Colza	1,2 - 2,0	40 - 55	480 - 900
Peanuts	1,2 - 3,0	30 - 40	360 - 1200
Soyabeans	1,3 - 2,0	16 - 22	240 - 660
Cottonseeds	1,3 - 2,0	14 - 16	170 - 320

Table 11 Use of fuelwood in Brazil (1976)

End use	$\times 10^6$ ton
Domestic (rural)	40 ± 12
Domestic (urban)	12 ± 4
Agriculture	14 ± 6
Industry	13 ± 2
Commerce, Transportation	1 ± ?
Government, Public Services	-
Total	80 ± 14

Table 12 Agricultural areas in Brazil (million of hectares)

Use of land	1977	1985	Increment	% / year
Products for internal consumption	29.9	42.1	12.2	5.1
Products for export	15.0	24.3	9.3	5.5
Energy purposes	-	8.3	8.3	- 40%/year
Total	44.9	74.7	29.8	6.7/year

Table 13 Annual rate of growth of energy consumption (1979 - 1985)

Energy source	Rate of growth (%/year)
Oil	- 2.7
Gas	15.6
Alcohol	24.7
Hydro	12.0
Coal	23.0
Fuelwood	- 1.0
Bagasse	9.9
Charcoal	20.5
Primary energy consumption	6.7

Table 14 Potential savings for solar energy $x10^3$ TEP

Sector	Savings
Residential water heating	670
Water preheating in industry	250 to 1240
Agricultural drying	80 to 260
Irrigation	280
Water distillation	120
Total	1,400 to 2,500

Table 15 Primary energy consumption

Primary Energy	Bep/day		
	1979	1985	Increment
1. Fossil	1,090,000	1,277,000	+ 187,000
Imported petroleum	920,000	420,000	- 500,000
Local production	170,000	420,000	+ 250,000
Gas	10,000	25,000	+ 15,000
Coal	100,000	364,000	+ 264,000
Shale	-	25,000	+ 25,000
Nuclear	-	23,000	+ 23,000
2. Renewables	1,310,000	2,293,000	+ 983,000
Alcohol	38,000	145,000	+ 107,000
Bagasse	111,000	198,000	+ 87,000
Fuelwood	410,000	394,000	- 16,000
Charcoal	61,000	187,000	+ 126,000
Hydro	690,000	1,354,000	+ 664,000
Other	-	15,000	+ 15,000
3. Conservation	-	140,000	+ 140,000
Total	2,400,000	3,710,000	+1,310,000

Table 16 Overview of energy projections for 1985.

	Additional bep/day 1980-1985	Investments 1980-1985 USx10^9$	Dollars bep/day
Oil (local production)	250,000	8.0	32,000
Coal	221,000	5.8	26,300
Shale	25,000	1.5	60,000
Alcohol	107,000	5.2	48,500
Charcoal	126,000	0.4	3,150
Hydro	674,000	28.0	41,000
Conservation	140,000	1.0	7,100
Total	1,542,000	51.9	

FIGURE 1

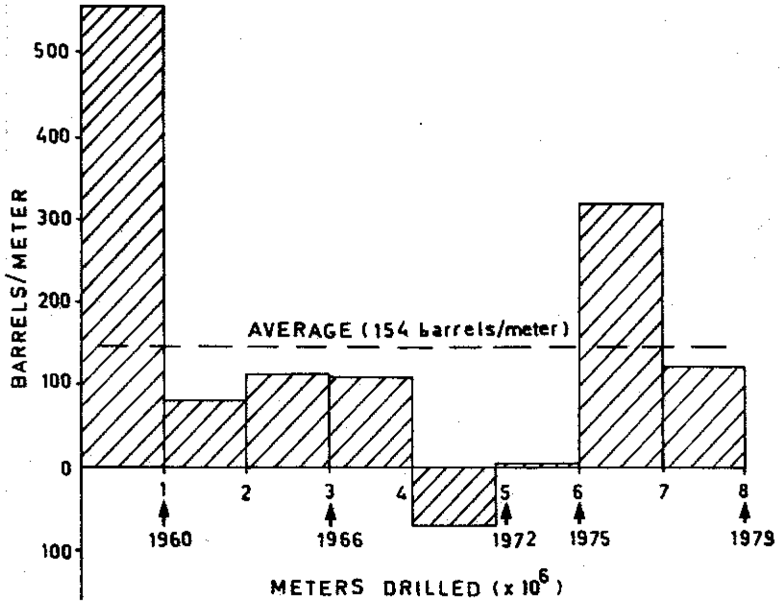
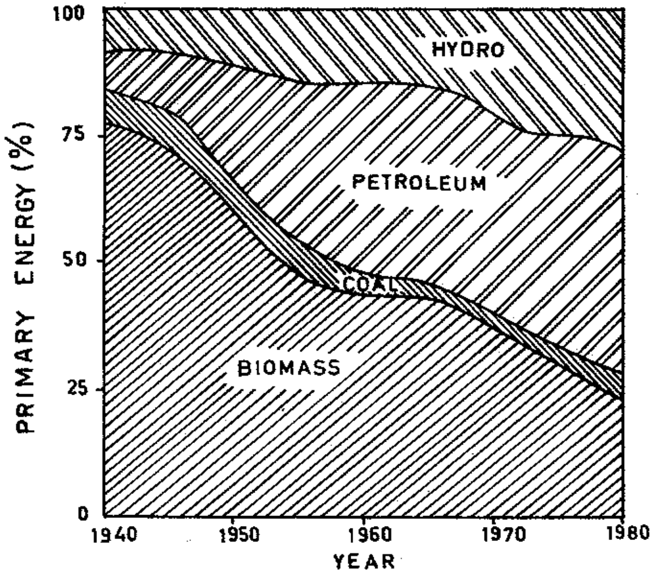


FIGURE 2



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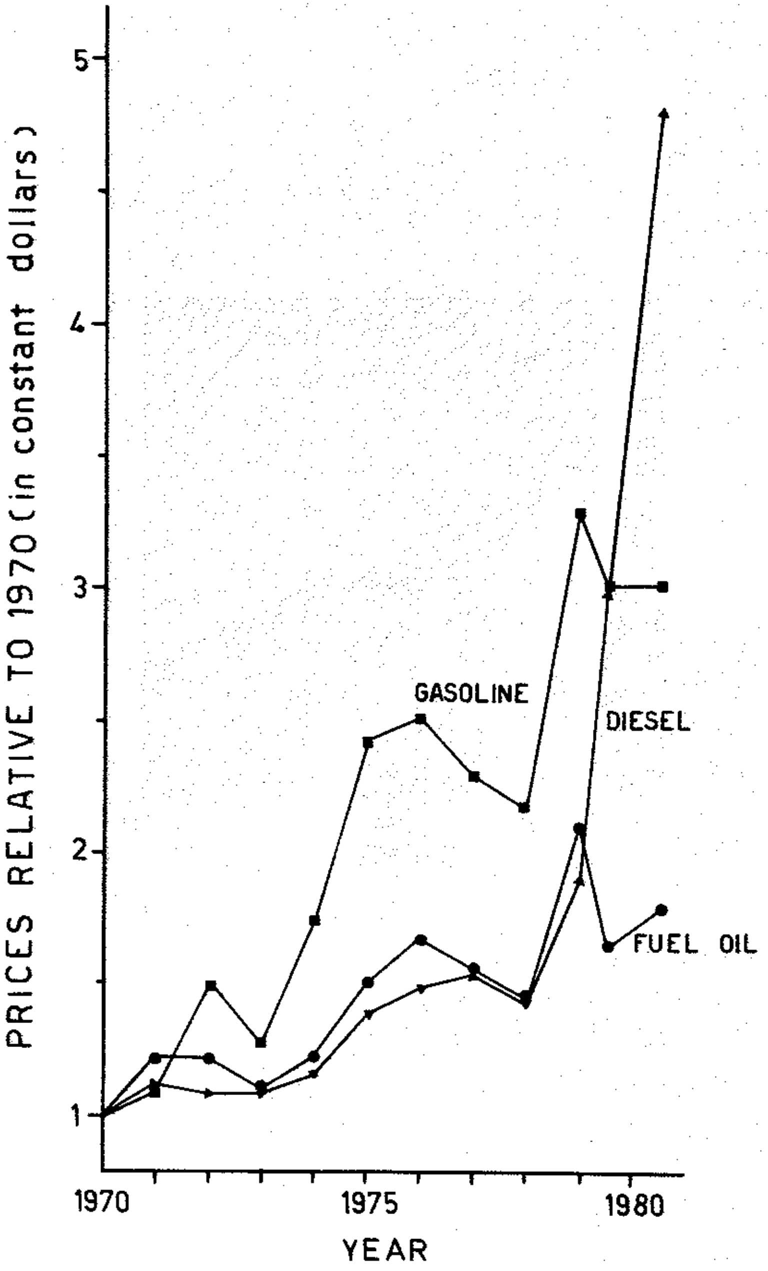

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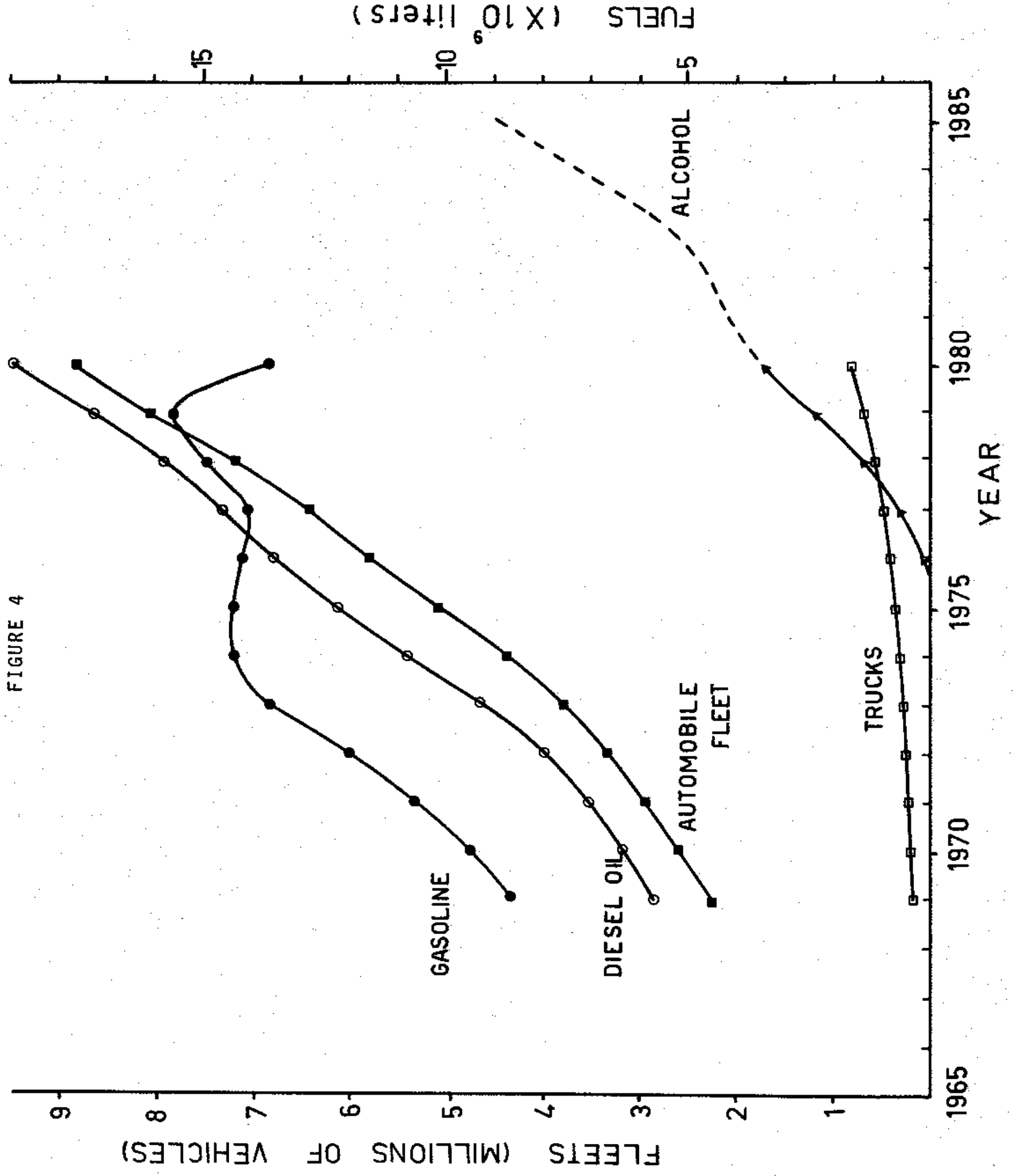

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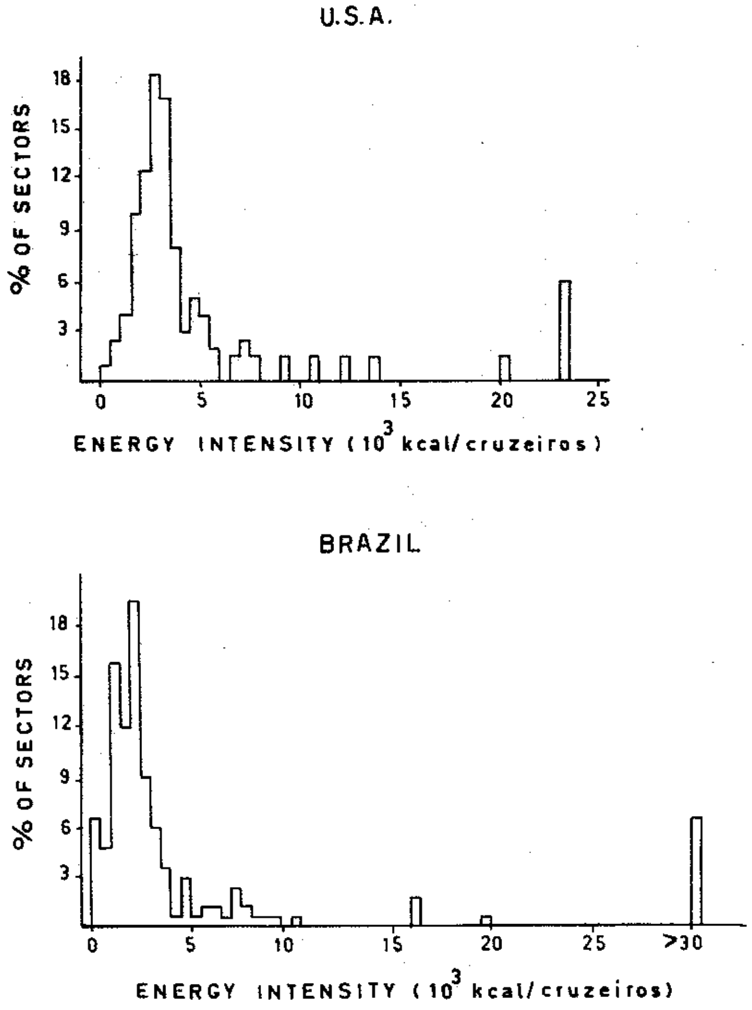

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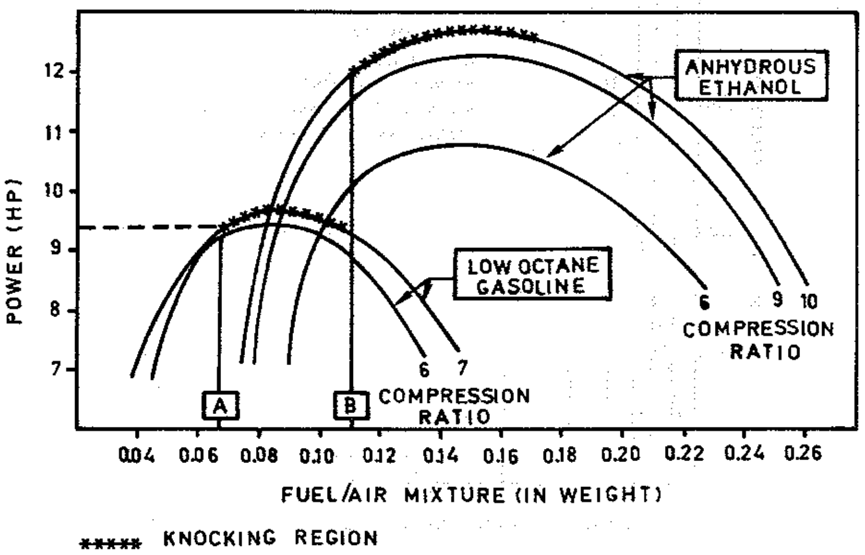

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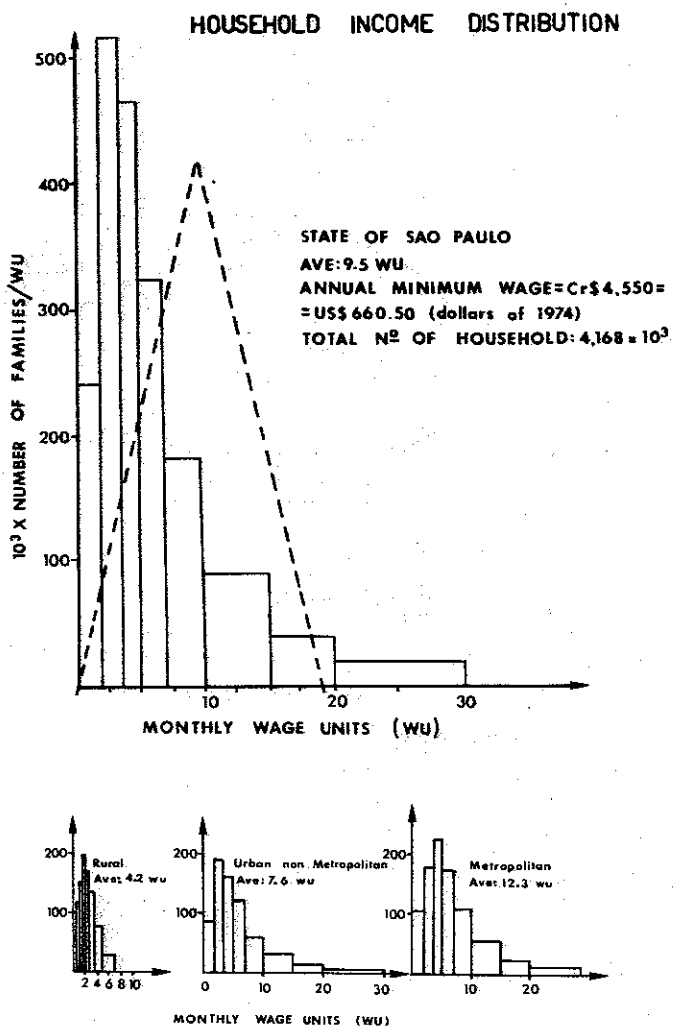

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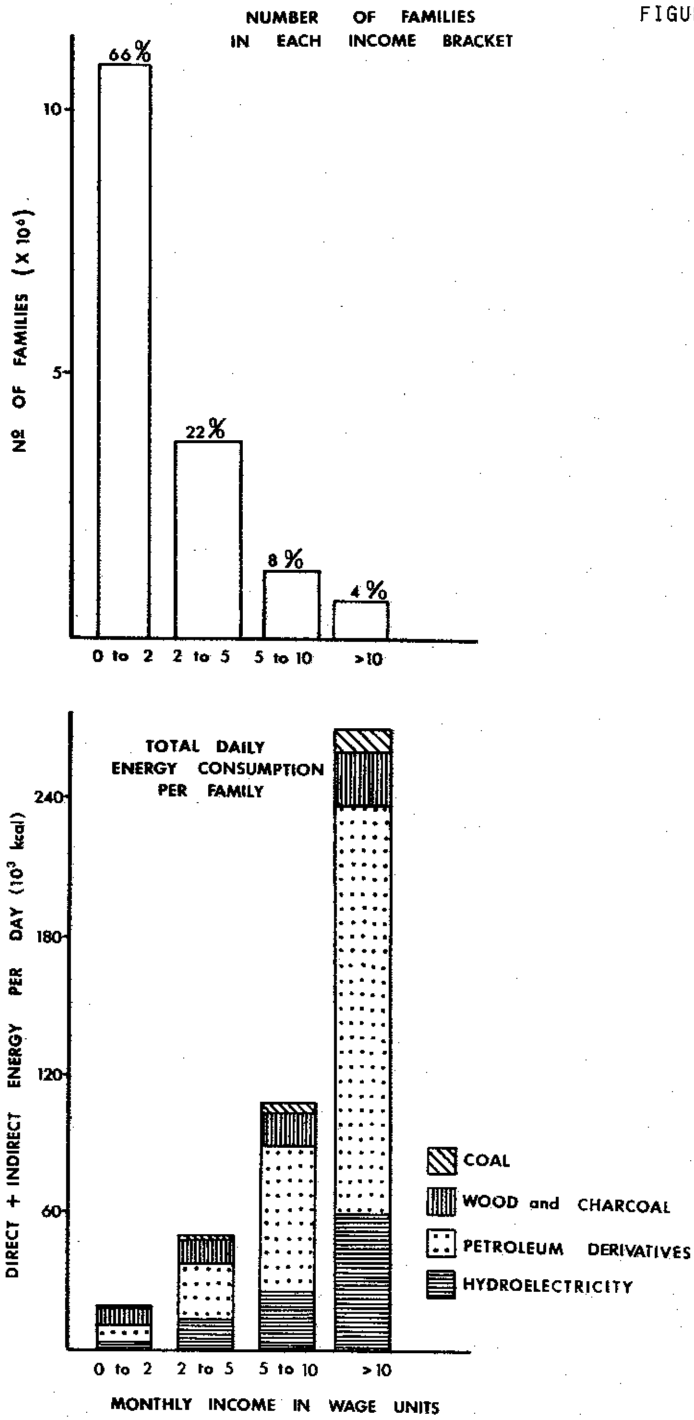

FIGURE 9

HOUSEHOLD ENERGY EXPENDITURES (STATE OF SÃO PAULO, BRAZIL)