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THE BRAZILIAN EXPERIENCE IN BIO-ENERGY DEVELOPMENT - A CASE STUDY OF THE PROBLEM OF SUBSTITUTION FOR DIESEL OIL

A report to the USDA/AID
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INTRODUCTION

Several things make the experience of Brazil worthy of note in the field of bioenergy development:

a) The priority given to its development by the government to supply the "modern" sector of the economy;

b) The existing scale of development and commitment of resources in the area;

c) The domestic technical resources available in a tropical developing country;

d) Not unconnected to the above, the steady pressure of a large and growing economy which is likely to have great difficulty in obtaining adequate sustained increases in domestic oil production.

e) The diverse sources of institutional funding at the development level which, has encouraged a corresponding diversity of working groups, more diverse than one might expect in a country with such a relatively strong federal power.

The second and third reasons cited above make the experience of particular relevance to many other developing countries, and by extension the development community. To a certain extent the reasons for this experiment, taken together, make Brazil unique.

This report will document some of this uniqueness, but in the end it is best not to dwell on the unique set of circumstances. This is after all the situation of most pioneers. What a pioneer does, the new information and understanding that he brings interests us more than exactly why he became a pioneer--though if he succeeds we are likely to be quite interested in his motives.

Before we inquire into motives it is necessary to determine motives for what, in a technical sense, and then in a more political sense. With regard to the first, technical, sense there is a tendancy overseas to be fixated on the alcohol (ethanol) program. This is understandable, but it is not very helpful. This is because there are at least two other mainstream programs underway, and several subsidiary programs that would be classified as important in any other country in the world. Of the two other big programs, one is already at a comparable scale of magnitude as the alcohol program itself (the reforestaton/charcoal program), and the other is aimed at diesel, the largest petroleum fraction consumed in Brazil. (The vegetable oils program).

The truth of the matter is that biomass plays a central role in Brazilian energy planning that is difficult to comprehend outside of that country. The turning point came in 1980 under the combined pressure of the general OPEC 1979-1980 price rise, and the very specific insecurity which Brazil felt as a country dominantly dependent on Iraq for its crude oil. Together, they made alternatives more economic and concentrated the government's mind on the "non-market" costs of dependance.

Biomass is now seen as a resource to substitute for all fractions of petroleum, and the scale of the proposed impacts over the next decade is such that analysts of the petroleum sector must take them into.account in designing refinery strategy. The first task of the outside analyst is to understand the rationale for these programs, then to judge their reasonableness on economic and other grounds. This will also draw us inevitably to look at where they are going technically and in socio-economic terms. Only then can we begin to look at them through the optic of their relevance to other developing countries.

Faced with the complexity of this task, and limited time and resources on the other, the author has chosen to focus this report on the relationship of biomass with one key petroleum derivitive in Brazil's energy economy-diesel. This may seem to be a rather specialized perspective for a general review of Brazil's bio-energy programs. However, the critical role of diesel and the inter-connections of the country's fuel economy mean that virtually every important bio-energy program must be reviewed. At the same time it provides an illuminating and practical case study of issues involved on the substitution of petroleum.

Let us begin with an introductory look at the demand aspects of Brazil's petroleum economy. Until 1973-74, the three primary petroleum derivitives (gasoline, diesel and fuel oil) were all growing at more or less the same rate of 10-11% per annum. After that fuel oil slowed down and gasoline stagnated, while diesel continued to grow at its historic rate. The reason for the stagnation in gasoline demand was not principally due either to the alcohol program (which until 1978 was still too small to have much impact) or to conservation (people driving less or smaller cars) though by 1978-79 these were becoming increasingly important. The main reason was a massive shift from gasoline to diesel in the medium and even light truck class. This was driven by the strong and consistent increase in the price of gasoline relative to diesel which occurred starting in 1974. (Figure 1).

Starting in mid-1979 several important changes began to occur. First, the increase in international oil prices pushed energy to the forefront of attention again. Product prices increased sharply if briefly. A more lasting consequence was the decision to go to the second phase of Brazil's alcohol program (Proalcool). This involved a sharp increase in objectives for alcohol production principally to supply a fleet of cars fueled by hydrated alcohol that would reach 2,000,000 by 1984. This decision, unlike that calling for increased coal production, was actually supported soon thereafter by financial resources and a rough plan for implementation.

It soon became apparent that this initiative was as unbalanced as it was bold. Of the three petroleum derivitives only gasoline was the target of a viable program of substitution. Given the limitations of Brazil's refinery system this would lead to a glut of gasoline and/or shortages of other derivitives, especially diesel. One example of the diesel problem as it was viewed from within the biomass planning sector of the government is shown in Table 1.

As a consequence of this and, the steady intensification of the petroleum import problem in 1979-80, goals to substitute for diesel and fuel oil were promulgated by the National Energy Council in October 1980. Coal was to be the main resource for fuel oil substitution, but with important support from fuelwood, forest residues and charcoal. For diesel the substitute was to be vegetable oils. All the goals were very ambitious. Coal was to reach million tons, a seven fold increase in five years. Charcoal to reach 120,000 barrels per day of oil equivalent and planting rates of 300,000 hectares per year were to be achieved in 1982. Vegetable oils were to reach 3 million tons.

Six months later, things look a little different. Coal's objectives (never realistic) have been cut back by a third but considerable financial resources are beginning to flow from the Energy Mobilization Fund. Virtually nothing has been done at the government level in support of charcoal and fuelwood for oil substitution. Vegetable oils seem to have a substantial R&D budget and little more. On the otherhand, the government has taken aggressive action on prices. Table 2 shows how they have evolved over the last few months. The most important changes have occurred for diesel and fuel oil. Long priced below the world market price they are now above it, in the case of diesel significantly. This new price policy, <u>if</u> it is sustained, will be of fundamental importance. This is clearly the case with fuel oil where considerable improvements in fuel efficiency in industry as well as large scale substitution with alternative fuels or (possibly) electricity will be economically attractive. Fuel substitution is now beginning to occur at an impressive level as a market response, a point which we shall return to in greater detail later.

With diesel, the impact is a little harder to assess and is less clearly positive. Diesel is consumed in greater part in the road transport sector (Table 3). Within the freight subsector this price increase may stimulate some modal shift to the railways if the infrastructure is there (which it frequently is not). It will also stimulate the adoption of larger trucks and better diesel engines, but the former will also require changes in cargo handling for road transport - perhaps the critical limiting factor until now. All these structural changes will take time, and in the meantime there will be a large inflationary impact. In urban passenger transport (dominated by buses) the impact is likely to be almost purely inflationary. In mid-1980 almost a third of the cost of operating an urban bus was diesel fuel. Since then the price of urban transport has risen considerably faster than the consumer price index (table 4). This is particularly undesirable because buses are overwhelmingly used by the poorer strata of the population. In fact it is a bit of a mystery why diesel prices have been raised to such a high level so quickly.

It is possible that one important motive for this traumatic increase in diesel prices is to make substitution feasible with existing financial mechanisms for subsidization. Such a basis is fundamental to the implementation of a program like that for vegetable oils, but until now it has not existed. If this was indeed a motive, it is unlikely that this reconstruction of the market will be enough to bring vegetable oils into the fuel economy at a rate anywhere near that originally established. This is probably just as well, because vegetable oils appear increasingly to have been the wrong choice, at least as a major alternative to diesel in this decade. The additional tax resources made available by this price increase would be better spent elsewhere.

Having said unkind things about this program let us turn now and look at it in somewhat more detail.

VEGETABLE OILS - THE FRONTAL ATTACK ON DIESEL

When in October of 1980 the National Energy Council (CNE) authorized the start-up of this program targeted specifically to substitute for diesel oil, the objective was to achieve a production of 3 million tons of vegetable oils for fuel purposes by 1985, equivalent to 16% of diesel (using a common official projection of 25.7 million m^3 of diesel, 11-13% would be more correct) (ref 25, p. 16).

There would essentially be two phases to the program. Because of biological constraints raw material production would first have to be dominated by annuals. Later, perennials would increasingly dominate. The crops most frequently mentioned have been:

Annuals	Perennials
Peanut	Babassu palm (orbynia martiana)
Soybean	Oil Palm (Elaies guineensis)
Cotton	Coconut (Cocus nucifera)
Sunflower	Pinhao (Jatropha Spp)
Rape Seed (Brassica Compestris)	Avocado (Persa americana)

In general, the yields of perennials are higher than those for annuals (Table 5) and it is hoped that they will prove cheaper to produce. From discussions with government officials, it is clear that the great longer term hope is oil palm (dende in Portuguese). Despite the fact that the international price is about $450-480 per ton compared to about $300/ton for diesel, the government is firmly convinced that oil palm can be produced for about $300/ton with current technology. This conviction is based on a consultant's report which, needless to say, is not available for outside evaluation. If the government is right, then oil palm is indeed interesting.

For the decade of the eighties, however, the perennials are almost irrelevant. With the exception of coconut (coco-da-Bahia in Portuguese) harvested areas are insignificant, and experience limited (Table 6 gives harvested areas) and lag times from planting to a full rate of harvest are generally five years or more.

Concerning the annuals there has been considerable confusion. On the one hand rapeseed and sunflower were highlighted by Antonio Licio (co-ordinator of energy programs of the Ministry of Agriculture) as the primary competitors with diesel (ref 25, p 16). On the otherhand, the total area in cultivation in 1980 of these two combined was less than 70,000 hectares (almost all that in sunflower) (Table 6). Rapeseed is just leaving the experimental stage in Rio Grande do Sul (ref 25, p. 37), but because of good technical groundwork it may conceivably, with strong economic incentives yield 450-700,000 tons of oil by 1986-88 in Rio Grande do Sul (1-1.5 million tons of grain at 45% oil), occupying 500,000-1 000,000 hectares as a winter crop in a two crop rotation. There is a slight catch, however. It will substitute for other crops. In the winter rotation it competes directly with wheat (which will then have to be imported). This does not mean rapeseed is bad (indeed the original objective in Rio Grande do Sul was precisely to find an alternative to wheat, which has not done well), but there is an opportunity cost. The extent to which rapeseed can be quickly extended to other areas in the South is unclear. There is also potential in the cerrado, but this will presumably be a longer term matter.

Sunflower, has a similar yield of oil per hectare as rapeseed and appears to have grown rapidly (from 10,000 hectares to 65,000 hectares between 1977 and 1980), however, there is very little information on costs or yields. Past attempts at dissemination have failed because of disease problems (ref 26).

Thus, despite their higher potential yield, and possibly lower cost, (Table 8) these two crops are unlikely to dominate vegetable oil production over the next decade. An interesting, if speculative exercise in this regard was carried out for the Ministry of Mines and Energy in mid-1980, and is shown in Tables 9 and 10. Rapeseed and sunflower account for less than a quarter of the production and a third of the area* in 1985.

Although Brazil is a major world producer of vegetable oils (or their raw material), largely on account of soybean production, it is clear that anything like the program goals represents an enormous acceleration in production. The original goal for 1985 is only a little less than the total potential oil producton today. Furthermore, about 90% of this production potential is in two crops which everyone agrees are not very appropriate for a diesel/oil program - soybeans and cotton because of their low oil yield per hectare and the dominance of their "by-products". This means that tremendous growth must be experienced with smaller crops.

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*The target for 1985 in this exercise (ref 27) was lower than later announced. It is also worth noting that the yields tend to be slightly optimistic.

The extraordinary urgency of these goals led the government into confrontation with the major diesel manufacturers in Brazil (Mercedes, Scania, Volvo, MWM, Detroit, and Caterpillar). First of all the government wanted warranties quickly, and, for the least refined vegetable oil possible. This was clearly required if the program was to meet any thing like its goals. It was also clear, however, that nothing like the depth of testing had been done to guarantee the impact of vegetable oils of any sort for engines supposed to operate for 500,000 kilometers or more. Furthermore, it was clear that for normally refined vegetable oils, there were important problems. These are most severe in direct injection diesels, where carbon deposits build up rapidly. Indirect injection diesels are considerably more tolerant. Unfortunately, direct injection diesels account for the overwhelmingly greater part of diesel consumption in Brazil (as in the rest of the world outside of the market for small high-rpm engines, such as diesel cars). Any attempt to reverse this dominance would be retrograde from an efficiency point of view, since direct injection diesels are about 15% more efficient that indirect injection. Finally, an obvious problem remains with use in indirect injection engines and that is a strong smell in the exhaust which has been described as "intolerable" (ref 25), and apparently results from incomplete combustion products of glycerol. It is not clear if the smell problem exists with direct injection diesels.

These problems appear to be overcome with various treatments to crack the relatively large multi-branched triglyceride molecule characteristic of the vegetable oils under consideration. The most prominent of these treatments is a low temperature trans-esterification process using either methanol or ethanol as the catalyst (ref 25). Unfortunately these processes, while probably industrially feasible, are at the bench scale, and there is not even enough output of the esters for engine tests.

As if this were not enough, there are the problems of economics. First, as is widely observed the value of these oils on the international market is considerably higher than their value when substituting for diesel. In some cases a sharp increase in Brazilian production may bring down the price. Government representatives claim that in fact they will not divert new vegetable oil production into diesel substitution if it has a higher price on the international market (ref. 25). This may be fine, on the face of it, for agricultural producers, but this strategy of deliberate uncertainty will probably cause severe problems further down the line. If, as seems likely, special cracking will be necessary, it is hard to imagine investment on a large and consistent scale with a "maybe we will, maybe we won't strategy". This kind of shifting can only work at the margin for horizontally integrated firms (as with annexed alcohol distillers).

Second, not only is the opportunity cost high, but the cost of production is high relative to the diesel which would be substituted. Tables 7 and 8 summarizes preliminary economic calculations by the Institute of Technical Research (IPT, in Sao Paulo) for vegetable oils. The calculation uses the discounted cash flow method with a discount rate of 10% and inputs at market prices. The costs for annuals would range from $90 and $100 per barrel of diesel equivalent. This is a high price to pay with diesel at $40 per barrel on the world market. It is possible, however, with diesel in Brazil now at $68 per barrel (retail) and with the kind of nominal cost reductions possible with existing subsidized lines of credit, that the two cheapest vegetable oil sources that are annuals (sunflower and rapeseed) may be close to competing. This prognosis is complicated by two things. First, while nominal cost reductions due to subsidized agricultural and targeted industrial credit averaged 30-35% for ethanol, which may be taken as indicative for vegetable oils (See Table 11) these reductions were characteristic of the subsidized credit structure t existed prior to the financial reforms which were instituted in December 1980/January 1981. These reforms have been designed to reduce subsidies, and since this is an overall economic planning priority it is rather unlikely that a special case would be made for vegetable oils (if the financial planners let this exception in, there are two dozen more strongly organized ones pushing at the door).

Second, the costs cited appear to be for regular refined oils, not the "cracked" oils which the diesel industry insists (probably rightly) are necessary "cracked" oils will be more expensive. Finally even if these two sources are competitive, there potential growth, in absolute terms, is rather limited, as already pointed out.

On the otherhand, even at substantially reduced subsidy, and with costs of trans-esterification (or some other form of "cracking') oil palm could probably be a winner.* This is without considering social cost-benefit analysis which, in this case could be quite favorable. As has already been mentioned, however,

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*See Table 8. Note that this IPT estimate is quite a bit higher than the official government estimate ($430 per ton compared to $300 per ton).

oil palm is a longer term resource. Also planting of oil palm would depend on a firm long-term government policy regarding diesel price. Firm long-term government policies are a scarce commodity in Brazil.

There is a final, and by itself overwhelming, reason against the expansion of vegetable oils at anything like the rate envisaged - the conflict with other agricultural objectives, principally export crops, domestic food production, and now the alcohol program. The prospect of putting 5 million hectares into production in five years to substitute for only 10,000 barrels per day as suggested in Tables 9 and 10, is simply a hallucination. The growth in harvested area for a total of virtually all crops in Brazil has been 3.25% per year from 1966-68 through 1978-80 with a tendancy to decline. Given a current harvested area of 48 million hectares, this trend implies a growth of 1.6 million hectares per year. Over the last five years the average rate of increase has been 1.2 million hectares per year.

The situation is disturbingly tight just with the alcohol program, as discussed in detail by the author in reference 34. Even to meet these prior objectives will probably require a 20% expansion beyond trend. To add another 30% or more, in the judgment of the author, is to invite failure. It is not even clear that a "modest" program of say 300,000 hectares per year of annual oil crops (instead of more than a million hectares) could be accomodated without significant adverse impact, especially on domestic food supply and inflation. In terms of annual growth in area even this modest program would be two-thirds of the alcohol program, but by 1986-87 would substitute for less than 5% of diesel and would not contribute appreciably to establishing the infra-structure for higher yielding and (perhaps) lower cost perrenial cultures which might contribute in the 1990's.

ALTERNATIVES TO THE VEGETABLE OIL PROGRAM OVER THE NEXT DECADE

A number of alternatives have been suggested for approaching the diesel problem over the next ten to fifteen years. These are:

a) Reduction in diesel demand through conservation measures;

b) Reduction in diesel demand through a shift to "Otto-cycle motors"* for a significant part of the truck or bus fleet currently projected to use diesel;

c) Use of gasogens converting solid fuel for use in diesel motors;

d) Use of ethanol in a dual-fuel mode in diesel engines to substitute partially for diesel;

e) Use of ethanol with additives to substitute completely for diesel in the engines in which it is used;

f) Increased substitution of gasoline by ethanol and use of excess lighter petroleum fractions to mix with diesel.

To these suggested alternatives, the author would like to add another, not yet articulated:

g) Increased conservation and substitution of fuel oil in industry with investments in refining to crack the excess to diesel. The domestic fuel to substitute could be coal or various biomass resources including wood or charcoal from natural and planted forests and various agricultural or forest residues.

These alternatives are not all mutually exclusive, and in fact several are almost certain to occur simultaneously. Furthermore, if we start to throw in all the variables, the analysis will become far .. complex for the modest

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*Including stratified charge engines.

effort in this paper. The author will therefore simplify drastically, which in this case means for the most part leaving aside the business of projections (the ten or more projections which would be required). He will concentrate on relative costs <u>at the margin</u>, without specifying quite where that margin is or how big the substitution would be. This is not very satisfactory. For example it is possible that conservation of diesel (option a) combined with mixing into diesel the automatic excess of gasoline/maptha generated by low automobile fleet growth (a distinct possibility) and full achievement of Pro-alcool goals will pretty much resolve the diesel problem through the mid-eighties. Let us however cast these nagging doubts aside and plod steadily ahead. The simplified approach assumes that someone will have to decide to augment the production of some supply alternative over what is actually happening, be it ethanol for options (b), (d), (e), or (f) or something else for options (c) or (g). While this crude approximation may be wrong, it at least has the value of responding to the dominant diagnosis of the problem in Brazil. (From the point of view of other developing countries this starting assumption is even more unambiguously valuable since they don't yet have an iron-clad alcohol program to complicate matters at the margin.). The simplified task that has been set is to determine the cheapest and most resilient strategy to achieve this substitution.

Before passing to this task, let us glance at option (a) conservation, an independent and essential strategy which must complement any of the supply options to be considered. With diesel at a new high price it is also something of a wild card. It is not possible to predict how the Brazilian transport system (which has already demonstrated considerable price sensitivity) will react to the unprecedented increase in the cost of a fundamental input. The limited projection/planning work available to the author antedates this drastic change, and is thus, to some extent, obsolete. It is interesting as a start, though, because it projects the greatest conservation in precisely that area which is likely to be least price sensitive (urban bus transport) - and as a consequence indicates considerable pessimism regarding savings in the freight sector (which is unregulated and more price sensitive). The plan of the Ministry of Transport is to reduce the base projection of diesel from 25.8 million m^3 in 1985 to 22.7 million m^3, saving of about 12%. Essentially all of this saving appears to be attributed to urban collective passenger transport. Within this sector 10% is expected from the implantation of passenger railways and electric trolleybuses and 90% from the rationalization of bus transport (ref 24). This is an enormous saving and appears to be almost an extrapolation throughout metropolitan Brazil of the experience of the city of Curitiba which has reduced bus fuel consumption of 30-40% through rationalization. Curitiba's success however, is due to long-term consistent urban planning and it seems very unlikely that savings on this order can be achieved in most Brazilian cities in five years (ref 31).

Let us now return to the supply side of the picture. As noted already, options (b), (d), (e), and (f) involve different alternatives for harnessing increased ethanol production. Two of these (b) and (f) represent the two supply options most actively explored by the government until now. The other two options (c) and (g) do not depend on ethanol. One of these two, the widespread use of gasogens (option c) can be dismissed immediately as a big league alternative for transport, through there are interesting specialized applications. On the otherhand, option (g), the conservation and substitution of fuel oil, combined with cracking of the resultant excess to diesel appears to be superior to the various ethanol-based options.

THE SUBSTITUTION OF DIESEL WITH ALCOHOL

Of the options being considered, two involve the direct substitution of diesel by ethanol that is:

d) A dual fuel system which essentially involves a change of the motor to accomodate the new fuel.*

e) An alcohol/additive system which allows the new fuel to be used in the same engine design (though some new materials may be needed in the fuel supply system, and of course, a new injector.

Both of these appear to be approaching technical viability. However, the government has shown a preference for the indirect substitution option, that is:

b) A shift to Otto-cycle engines;

f) Mixing excess naphtha displaced by alcohol in Otto-cycle engines.

*There is in this broad cateogy of "changing the motor", another option being more actively research by the Companhia Energetica de Sao Paulo for methanol is the "glow plug" which appears to be near technical viability and permits the use of methanol despite its low cetane rating (ref 35).

The basic reason for this preference is that a given volume of ethanol can substitute for a larger volume of gasoline than of diesel. In Brazil today gasoline has quite a low octane number, and as a consequence gasoline engines are built with a relatively low compression ratio (about 8) which results in relatively low efficiency. An engine optimized for pure ethanol use can have a higher compression ratio (about 12) which is one of the principal reasons why alcohol is used more efficiently. Estimates of this increase in efficiency vary among sources as can be seen in Table 12. For example IPT, in its economic analysis, implied a 20% increase. The World Bank, 35%. Closer parametric studies suggest that it is in the vicinity of 25% at most. This implies that one liter of hydrated ethanol (94%) will substitute for .77 liter of gasoline. In diesel engines, ethanol is not consumed more efficiently so one liter of ethanol substitutes for only 0.60 liter of diesel. The fun paradox in this is that, as shown in figure 2, ethanol is consumed more efficiently in diesel cycle engines (direct injection) than it is in Otto cycle engines optimized for its use. (At least with today's technoloy or anything on the horizon).

To a certain extent the efficiency of ethanol relative to gasoline gain is arbitrary. An infrequently asked question in Brazil is "why not increase the octane level of gasoline and increase the efficiency of gasoline motors?" Brazil has in fact already increased the octane of its gasoline (which is 70 when straight) by adding considerable amounts of ethanol which, as everyone knows, is an octane enhancer. The problem is that the mixture, which reached 20% in 1980, will have the alcohol content reduced drastically over the next five years as the alcohol car fleet grows. The first step will reduce it to 12%.

In fact, no one really knows what the level will be in five years. It could even be near zero. The gasohol mixture is essentially seen as a surge-tank for the alcohol car program. Under these conditions it is not surprising that gasoline engines are not being manufactured to optimize use of (say) a minimum 10% alcohol mixture plus other measures which might increase the octane rating up to (say) 85 instead of 70. It is in fact curious that the pure alcohol car's economics are being credited with a full improvement over the present low efficiency of gasoline engines when a very strong case can be made that the alcohol car program is helping to keep gasoline performance bad. As if by magic, an opportunity cost has been converted into a credit.

The reality, though, is that in Brazil over the next few years ethanol will substitute for 25-30% more gasoline then diesel. With diesel there is no room for manoeuvre (legitimate or not), the substitution is straight and simple - one kilocalorie for one kilocalorie.

In this light, ethanol looks almost as bad economically as vegetable oils, coming in at $70-80 per barrel of diesel equivalent, approximately double the world market price. It is possible that in the 1990's ethanol will be able to compete more effectively for the diesel market, and indeed, given the trend to dieselization
of all sectors of the transport economy, including cars (Figure 5 gives an idea of embryonic trends in 1970's) this would be the preferred market from a policy perspective. For the eighties, the short term, it is not very viable.

The first indirect option that we will look at is the shift of a part of the existing diesel fleet back to Otto-cycle engines. This approach was being actively explored by the government, with ideas being proposed such as making sales of new diesel trucks below a certain weight illegal. The objective here would be to reverse the truck market's reaction in the 1970's to the sharp increase in the price of gasoline relative to diesel. Unfortunately, it makes no energy or economic sense. We start with the alcohol production that would generate the excess. In order to replace 100 liters of gasoline we would need to produce 124 liters of ethanol (anhydrous basis). This gasoline, used in Otto cycle engines would accomplish the same work as 60 liters of diesel. Since 100 liters of alcohol can substitute for 60 liters of diesel oil in a diesel engine, this strategy uses, about 25% more alcohol than a direct substitution of alcohol by diesel. Instead of $70-$80 per barrel of diesel equivalent we are now talking $90-$100 (based on the IPT cost estimates in Table 8). To this must be added the gross distortion of the vehicle market which would be caused by such an arbitrary intervention. Needless to say the diesel and truck manufacturing industry fiercely resisted this proposal and it now appears to be dead, at least in the form of prohibiting sales. The recent elevation in the price of diesel relative to gasoline could be interpreted as a move to achieve the same result through the mechanism of adjusting the fuel price. So far, however, this readjustment is not sufficiently large to force diesel users back to gasoline. In mid-1976, when gasoline trucks were heading rapidly towards extinction, the difference in the price of gasoline and diesel was about $28.00 per barrel. Today, despite the recent increase in diesel price as a percent of gasoline price it is about $65.00 per barrel. This absolute difference is what is critical in consumer's decisions. The Planning Ministry is talking of raising the ratio of price from today's level of 50% to

80-85% more or less the ratio which existed before 1974. This would give Brazil the most expensive diesel fuel in the world. It is hard to imagine any other single energy policy initiative which could unite more disparate groups in opposition. In so far as it is safe to say anything about the future in Brazil, it is safe to say that the price policy will not happen. It is also safe to say that trucks will not be forced back to use gasoline.

The second option is quite different, and is in fact already happening. Increasing amounts of naphtha/gasoline are being shunted into the diesel fraction in the refineries of Petrobras and diesel specification have been modified to accomodate this change (Ref. 35). This is an inevitable result of the higher rate of growth of diesel and LPG demand compared to gasoline demand with even a partial accomplishment of the Proalcool targets.

The question is, however, whether the goals of Pro-alcool should be increased, or perhaps more realistically, should every effort be made to achieve the goals of Pro-alcool when indications currently suggest that they will not be met.

The problem of supply could be serious, though the government adamantly claims it is not. As Table 13 shows there has been a 10% shortfall in targets in both 1980 and 1981. (The 1979-80 harvest which began in June 1979 and ended on April 1980 counts as 1980 using the statistical conventions for harvests in Brazil). A specialist contacted by the author suggests that the shortfall in 1981 was due to lack of capacity. This sort of temporary shortfall can in principle be made up, but it may be endemic because of delays in start-up. The issue is obviously complex and the author does not claim to have enough information to make any kind of certain judgment, observers should however be alert to the possibility. A 20-25% shortfall would not surprise the author, and one specialist (Estado de Sau Paulo, 16 May 1981, p 27) has gone so far as to project a 35% shortfall in 1985.

The key problem is that it appears to take 4-5 years for an autonomous distillery to reach full capacity. The World Bank, in its economic analysis (ref 20, p 103) assumed that production would only begin in the third year after investment began. In that year production would be 60% of full capacity, rising to 90% in the fourth year. Autonomous distilleries are representative of the new capacity scheduled to come on line--for example between the end of September 1980 and the end of March 1981, fully 75% of the new approved capacity was for autonomous distilleries (see tables 14 and 15). To this we must add the fact that to be producing at full capacity for the 1985 target year in the dominant Central-South region a destillery must be operating at full capacity by about June 1984. That is already only three years away. This would suggest that only the 900,000 m^3 of pre-Proalcool capacity plus 5.4 million m^3 of new capacity approved through June of 1980 (ref 20) will be operating at full capacity, plus some fraction (perhaps 75% of 2.4 million m^3 approved from then until the end of March 1981). This yeilds about 8.1 million m^3 of ethanol compared to the 10.5 million m^3 target. The April 1 cut-off assumes that some time is needed between project approval and actual liberation of funds to permit investment to begin. This is not a trivial step. At least 15% of the approved projects are currently hung up in legal problems. (See note to table 15). While some of the assumptions may be somewhat conservative, relying on "approved" projects as a calculation base is clearly optimistic.

Seen in this light, to speak of augmenting production beyond current targets, even for 1988 (14.5 billion liters) may not be realistic. If we want to substitute more for petroleum we must probably look to another resource. Furthermore, the economics suggest that we may want to.

Let us compare, in a very preliminary way the economics of substitution for diesel indirectly with, (a) ethanol displacing naphtha/gasoline and (b) fuelwood or charcoal displacing fuel oil to be cracked into diesel. The basis for this comparison will be the results of the IPT analysis, an analysis which in fact has been used to support the gasoline displacement option (ref 21), apparently on the erroneous assumption that refinery capacity could not be modified to crack fuel oil.

Looking at Table 8 the reader will see that the cost of production sufficient to substitute for one barrel of derivitive is about $17 per barrel for charcoal and about $60 per barrel for ethanol. This comparison is incomplete. Table 16 takes us one step further, by including transport costs to the user, and the higher cost which the user must pay for the equipment to use the fuel. The charcoal/fuel oil option loses some ground (in part because we've assumed the transport distance for charcoal is twice as far), but it is still only half as expensive with a 10% discount rate. Table 16 does not complete the comparison. The charcoal/fuel oil option requires some more refining costs. The estimates of relative cost are also preliminary, but with a margin of more than thirty dollars per barrel of oil equivalent there is plenty of room for error.

The use of charcoal from planted wood in this comparison is intended only as an example of a basic strategy to substitute for oil primarily in the industrial sector. Such a straegy would use a variety of resources, including coal. However, while this approach seems to be satisfactory from the point of view of comparative economics at the margin, it is important to consider barriers which may reduce the rate of which this strategy can be implemented.

PROBLEMS CONFRONTING THE EXPANSION OF OUTPUT OF BIOFUELS FOR INDUSTRIAL USE

The rate at which biomass fuel production for industrial use can be expanded is poorly understood but it is probably capable of faster expansion than either alcohol or vegetable oils. There are three distinct resources available today; planted forest, natural forest, and agricultural residue.

Planted forest must eventually be the backbone of supply, however, in the short-term it's potential is limited by the lag between planting and harvest. This lag need not be as long as is commonly supposed, the best practice in Brazil is moving towards high densities and a four year time to the first harvest. This is about the same time required to bring an ethanol distillery into full production. This practice is, however, not fully proven and not widespread. The standard practice is still that fixed by the IBDF for approval of financing - a 7 year rotation and 1665 trees per hectare.

Nominally, at least, Brazil has a considerable industrial infrastructure in place to carry out the necessary planting. Figure 8 shows how the annual rate of planting evolved from 1967 through 1978, including that for the genus eucalyptus (the only genus being seriously considered today for energy purposes). The rapid growth shown here, was not as impressive as appears at first sight. The nature of the incentives (essentially a tax credit) tended to discourage innovation, and to encourage fraud, sloppy planting and poor connection with any discernable markets. Fully 40% of the forest planted in Minas Gerais had no defined market in 1979 (ref 32). Even where markets were supposedly known the production did not match expectations. Figure 3 shows IBDF projections of charcoal output from planted forests. In theory, charcoal output from planted forest should have approached charcoal demand in 1980. In fact it was only 20%. The problem was most severe with independent reforestation companies. It is estimated that the 630,000 hectares planted by then had a miserable yield of only 10 steres per hectare per year in 1978 (about 3.5 tons) (ref. 30).

This experience with fiscal incentives, plus their high cost to the Federal treasury (which makes them very sensitive to short-term fiscal crises), makes their substitution with another financing mechanism almost a pre-requisite for a successful large scale program of energy plantations. There is momentum to shift financing over to bank credit, and a World Bank project to encourage this shift is an early phase of developent. In the meantime, however, Brazil must make do for several years with a sub-optimal mode of financing, phasing in lines of credit from mid 1982 on (at the earliest). There is some indication that the oversight agency, IBDF, is now somewhat more capable of honest and technically flexible management than in the past.

In speaking of capacity, it is important to take into account competing requirements for reforestation. Existing capacity was not, after all, developed with energy requirements in mind. A rough estimate of the reforestation requirements of these other demands (charcoal for the iron and steel industry, paper and pulp, and processed wood) together with an equally rough estimate of potential producton capacity, is shown in Table 24. These estimates were prepared in 1979 by a working group for the Secretariat of Industrial Technology (STI) (ref 30). The Table indicates a considerable reserve capacity which can grow quickly and one might as a first approximation move the agenda ahead two years, to start in 1982 with 500,000 hectares per year. However, these estimates must not be accepted uncritically. We have already seen hints that some of the 200 firms constituting this capacity have not yet demonstrated technical competence, but there may be a more fundamental constraint - seeds. Table 25 shows the seed requirements as estimated by the STI working group using to grow of seed per hectare. the estimates of the group showed that if Brazil launched an agressive planting program in 1980, supply shortages would occur as early as 1982 unless a very active program to develop domestic seed production capacity was begun immediately (in 1979/80). The two principal exporters of Eucalyptus seed, in the world South Africa and Zimbabwe were estimated to have an export capacity of 20,000 kg per year (ref 30, p 113 - it is not made clear if this is total export capacity, or what Brazil could reasonably hope to import), and Brazil would be very close to this maximum import level with a planting rate of 370,000 hectares per year for energy. This figure was not much above the level being discussed a year later (in November 1980) for energy planting in 1983. The group found that an aggressive seed production program could grow quite rapidly (roughly a two year lag), so that in principle supply and demand could balance. However, in 1978 the actual use of seed, per hectare was considerably higher, about 75 g per hectare. An adjusted import requirement is shown in Table 25 using this historical rate of use. If the import constraint is indeed verified this implies a much more difficult constraint on growth. While it is possible that seed use could, with time, be reduced to the stipulated level with similar planting densities, there is likely to be a trend towards higher densities, combined with shorter rotations, which will increase seed demand per hectare. Since little has been done little to increase seed production since 1979, it is possible that total eucalyptus planting may be limited to about 300,000 hectares for the next several years. This implies 100-150,000 hectares for energy depending on the level of reforestation for other uses (100,000 hectares assumes the levels in Table 24 and an import limit of 20,000 kg). It goes almost without saying that any serious wood-energy program must give top priority to quality seed production. It is interesting that a decade after it first began planting 80,000 hectares or more a year of Eucalyptus, Brazil is still more than 60% dependent on seed imports.

This constraint suggests that no matter how optimistic we may be about yields and short rotations, the contribution of new planted forest will be quite limited through the late 1980's. This forces us to turn to the second resource, native forest, as a primary resource for increasing output in the 1980's.

In order to have a standard for comparison, however, let us first look at the magnitudes of wood which might be used in a substitution program and then turn to regional supply and demand balances. Various goals have been advanced from time to time for new substitution for fuel oil. The "energy model" of the Ministry of Mines and Energy proposed, rather simplistically 120,000 barrels/day (petroleum equivalent) of charcoal for this purpose by 1985.

For the purposes of discussion the author has chosen a more detailed set of estimates put together in 1979 by the Ministry of Industry and Commerce (ref 30). Table 21 shows how fuel oil consumption was expected to grow in six major consuming industries from 1980 to 1985. Table 26 gives the study's estimates of possible substitution in five of these industries reaching a total of 110,500 barrels per day in 1985. In order to acheive this, 31 million tons of wood would be required. These estimates are only intended to give a rough approximation of the quantities being considered. The tables are based on 1985 with serious implementation beginning in 1980. Although explicit government action outside of raising the fuel oil price has been minimal, it appears that the rate of substitution may, overall, be close to that assumed here. Business is very brisk in boilers capable of burning soid fuel. One major manufacturer (Companhia Brasileira de Caldeiras) reports that about 80-90% of the steam generating capacity it is manufaturing is being designed for partial or complete use of biomass fuels (with or without coal) (ref. 33). Two industries not even considered in the MIC/STI report (ref. 30), chemicals and petrochemicals, are showing keen interest. Table 26 is useful, however, because it gives at least a first conservative approximation of the quantities of wood and charcoal that would be required to displace the 110,000 barrels per day that people speak of.

The impact of this wood requirement on total wood demand is shown in Table 22. From Table 23 it appears that about one quarter of the 1985 demand could be supplied from existing planted forest. The fuel oil program essentially implies that the use of native forest must increase by about 25% instead of declining slightly (Table 23). A slightly different picture is obtained if we use the estimates from Table 13 which are from another source.

This table estimates a total demand for wood (excluding wood for fuel oil substitutions) rising from 134 million tons in 1980 to 153.2 million tons in 1985* (compared to 124.6 and 135 million in Table 22). This discrepancy is almost entirely due to a higher estimate of wood use for non-energy industrial purposes in Table 18. The source for this table (ref. 24) will be used principally from here on because of the regional breakdown available for demand and supply from native forest.

The regional perspective is crucial in evaluating the potential. This is evident from Table 19, which shows a large deficit of supply capability from natural forest (relative to demand in Table 18) in the northeastern, southeastern and southern regions of the country, precisely where the greatest consumption of fuel oil is located. The deficits are to some extent covered by plantations. In 1985 the total deficit of wood in those three regions was estimated to be 70 million tons, production from plantations in these regions may be about 30-35 million tons. All this is without fuel oil substitution. These figures are not very encouraging, to say the least. They are not the end of the story, however.

First it is interesting that the deficit in 1980 was estimated to be 88.4 million cubic meters (49 million tons). Discounting for plantations we are left with a deficit of 30 million tons which is somehow supplied. There are two explantations for this. First exploitation of wood may be more intense than assumed by reference 29 (for example, in Table 17, column F may be larger relative to column C). Second wood is moving in from surplus regions such as the center West states of Mato Grosso do Sul and Goias.

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*Using the multiplication factor of 0.55 to convert one cubic meter to weight in tons (ref 30).

Inter-regional movement will have to be a critical element of any program to substitute fuel oil with wood. Let us consider the situaton in two key deficit regions, the south and southeast, with the contiguous surplus center-west region. If we look at 1980, Table 19, the south and southeast have a total deficit of about 83.8 million cubic meters (46 million tons). The surplus from native forest in the center west region is 64.2 million cubic meters (35.3 million tons). Given the contribution of 20-25 million tons from existing plantations, there is in principle, enough additional wood supply for fuel oil substitution in 1980. (3-6 million tons). On the otherhand, in 1985 the supply situation looks unfavorable for fuel oil substitution. The deficit has grown to 84.5 million tons, while the center-west surplus is slightly lower - 34 million tons. Combined with wood from existing plantations (30-35 million tons) there is, in principle, an approximate balance. This balance does not, however, include the 25-35 million tons of wood which might be used to substitute for fuel oil in the three regions.

At this point, it is important to look behind the supply and demand estimates in Table 19. They are, of course, quite tenuous - but having made the caveat lector that all these numbers are prone to error-there is an observation which is more interesting. The basic wood supply figures in Table 17 suggest an elasticity of supply. In the three regions the volume of wood removed from areas under nominally sustainable harvest is only about 25% of the wood in the area under exploitation that year. This result is summarized in Table 20. It is possible that from a silvicultural point of view that a more intense rate of removal on harvested land would be undesirable, the rate of removal would increase from 25% to 36% if all the additional demand of say, 25 million tons were obtained in this way. There is, however, another large potential resource of wood - that from clearing forest for other uses (principally agriculture). This is estimated to be 150 million cubic meters a year (Table 20 column 6). Of this, approximately 25% is used. If this were increased to 40% about 23 million cubic meters of 12 million tons of additonal wood would be available.

This is equivalent to about half of the total additional requirement assumed here. The overall impression from these two examples is that a reserve capacity adequate to temporarily supply a rapid expansion for fuel oil substitution does exist in the native forest, especially in the center-west region. If this broad conclusion regarding resources is correct, the economics of converting and moving this wood in the form of charcoal suggest that 100,000 b/d of fuel substitution by 1985 could be a reality.

Table 27 shows the breakdown of costs for producing charcoal from native forest. The transport cost should probably be increased by 20%. Even so it appears that the price of charcoal delivered up to 1200-1500 kilometers by truck can be economic with fuel oil at current prices, and allowing for the higher cost for most end-users to build and operate the combustion equipment (ref 11).

This is clearly not the optimum transport system, and it would be a great help if some railway lines could be used, such as the line connecting Brasilia to the southeast. Such lines would allow the use of smaller trucks such as common Mercedes-Benz 1113 to collect the smaller loads of independent producers* in generally precarious road conditions. These loads would be fed

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*The charcoal from native forest is made by independent producers of whom there are about 6000. Their average production is less then 200 m^3 per month.

to the railway system from a radius of a couple of hundred kilometers. Similar trans-shipment could occur to larger more efficient trucks. As can be judged from figure 4, the fuel consumption per ton-kilometer in larger trucks (like the Scania 111 which can carry 26 tons of charcoal) is only 70% of that for smaller trucks. With trans-shipment the energy consumption for transport of charcoal over a distance of 1200 km should fall in the range of 7-8% of the fuel oil substituted by the charcoal (see figure 4 and reference 11) in the conservative case where all back-hauls are empty. This level of auxiliary energy input is tolerable (especially since it occurs more or less at the time when the substitution of oil takes place and other fuel inputs are insignificant in native forest production).

Transhipment of charcoal for this purpose should involve fewer problems than traditionally experienced for metalurgical charcoal because the fines caused by handling are not a disadvantage. For this activity to take place on a significant scale institutional and physical improvements in commercialization will be needed.

A possible example is the further evolution of trading entities capable of managing and financing stocks and putting diverse producers, transporters and end-users into a flexible and reasonably stable market relationship. A

**Gasifiers using the transported charcoal might be used. However, it appears, from test work by Massey-Ferguson in Brazil, that their energy efficiency is only 70% of that of diesel in diesel motors. To this must be added the cost, in terms of time, capacity or a larger motor resulting from loss of power (25-30%). Finally there is the cost of the gasifier itself (about $50 per originally rated horsepower at 70 hp). (Ref 7).

concrete version of this is an entity which can purchase from independent truckers on feeder lines delivering from producers, maintain a minimum inventory, and load larger trucks for shipment to consumers. Such trans-shipment points already exist, but usually organized for a single large consumer.

The transport infrastructure should be capable of adjusting to this flow, in part because it is not overly large (9 million tons of charcoal transported on average of 900 km by truck would require about 6000 twenty-ton trucks travelling 11,000 kilometers per month).

Another option could be to transport wood without prior conversion to charcoal. The Institute of Technical Research of the state of Sao Paulo (IPT) finds this to be the most economic option <u>up to</u> 600 kilometers by truck (ref. 19). The author is frankly incredulous about this competitive range* but if it is true (combined with a competitive range of 1200 kilometers by rail), wood may be an important alternative for substitution where considerable transport is needed (the great majority of cases outside of the forest products industries). The author, however, believes that unless wood densification techniques succeed at least 80% of the substitution outside of the forest products industries will be charcoal (the figure implied by the breakdown in Table 26 and the relative efficiency).

*For example, note that in Figure 4, the diesel fuel consumption per unit of fuel oil substituted by the load in the truck is the same for wood at 100 kilometers (Case A) as it is for charcoal at 750 kilometers (case B)

The third resource is agricultural residues. This is the least studied potential biomass resource and the author was able to find almost no literature of value on the subject outside of applications of excess bagasse from processing sugarcane for sugar or ethanol. This specific resource alone is potentially significant.

The processing of sugarcane in Brazil is, in general, quite efficient in energy terms. Almost all boilers operate at 150 psi with wet bagasse, and the use of process steam is excessive by modern standards. There are, as a consequence important opportunities to increase the efficiency of mills and distilleries. The author has seen no systematic attempt to calculate bagasse potentially in excess of process requirements, but at current levels of sugarcane, ethanol and sugar production it is likely to be on the order of 5 million tons a year, equivalent to at least one quarter of the industrial fuel substitution goal of 120,000 b/d mentioned earlier. Whether anything like this contribution will actually occur will depend on the rate of investment in more efficient equipment and the markets which the bagasse will supply. In addition to non-energy markets such as fibreboard, paper, animal feed and furfural, there is a major competing energy sector option - the generation and export of electricity, from the plant to the grid. Indeed, outside of Brazil, serious analyses of the use of excess bagasse rarely touch on its use as a fuel for other industries.

However, while electricity generation is the preferred energy option outside Brazil, and is still the most widely discussed one in Brazil circumstances there makes it somewhat less attractive than in many other countries.

Hydroelectric

power and domestic coal supply about 90% of the nation's electricity and the share is increasing. Use of fuel oil for centrally generated electricity has remained stagnant since 1970. It is probable that given the relatively large reservoirs typical of Brazilian hydroelectric plants there would be little, if any, saving in capacity over the next decade due to co-generated electricity from sugar mills and distilleries operating only six months of the year. Measures would have to be taken to allow year-round operation which, with the current state-of-the-art, imply converting the bagasse into a denser storable form.* The conversion step (whether densificaton or pyrolysis) is an important step in making excess bagasse practically available for other industries to use.

While there has been little if any systematic analysis of the trade-offs between electricity generation and export as industrial fuel, some industries are developing the capability to burn bagasse. The industrial fuel option in short appears to be gaining increased attention.

The situation with other important crop residues is more nebulous. The author could find no estimates of even the gross quantities of a field residues in Sao Paulo or for Brazil, although some work appears to have been done in the South for rice, straw and mill wastes. (Which the author could not obtain). While the theoretical quantities are clearly large, there are serious questions

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*Scientia, a small engineering firm in Rio de Janeiro is trying to develop a package which would allow year-around harvesting and operation, which would negate this requirement. Other measures to allow year-round operation - such as evaporating the cane juice or recovering the material from cane fields cleared for replanting - would not.

regarding the economics for such a dispersed collection and marketing system for anything but on-farm use or local agro-industries. There are also questions regarding the possible impact on soils.

In short, potential contribution from agricultural residues is so uncertain and has been studied so little that they must remain a question mark. However, use of even a relatively small proportion of total residues (say 10%) could have an important impact on fuel oil or diesel use at the margin over the next decade.

CONCLUSION

The basic conclusion of this work is simple. The most cost-effective way for Brazil to use domestic resources to supply its growing diesel requirement over the next decade at least is to substitute for fuel oil in industry and modify refineries to yield less fuel oil and more diesel and LPG. This also appears to be a more cost-effective program than to substitute for gasoline with ethanol.*

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*This can be seen from Table 8 and earlier discussion in the text. The economic analysis by the World Bank (ref 20) might suggest a different conclusion since it yields a rather favorable internal rate of return for an alcohol program substituting for gasoline at world market prices (20% in the base case) a conclusion which surprised many people. Three points should be emphasized with respect to this World Bank analysis:

1. It assumes continuously rising oil prices throughout the decade. If they are stable over the decade then rise at 3% per year, the Internal Rate of Return (IRR) falls from 20% to 14% in the base case.

2. A rather high substitution value is assumed for alcohol replacing gasoline (see Table 12).

3. Shadow prices are used for the economic analysis and reduce the overall cost of alcohol production by about 20%. While it is appripriate to use shadow prices, it is important not to compare one option with shadow prices to another one without. It would be useful to carryout systematic comparisons with at least a crude social cost/benefit analysis as the bank has done.

If we try to calculate the cost of production without shadow prices and a 10% discount rate, but using World Bank costs for inputs (which generally seem reasonable, though they tend to the low side), we get about 25.5¢ per liter (or $12.15 GJ). With a more conservative coefficient for substitution of gasoline by alcohol 1 GJ of ethanol = 1.2 GJ of gasoline instead of 1.35) the cost of ethanol per vehicle-mile would appear to be about 40% higher than gasoline.

It appears that the use of considerable woody biomass, including fuelwood from plantations, and some agricultural residues as a fuel oil substitute can be competitive with petroleum of current prices. However economic viability (outside of traditional user industries) only occurred beginning in 1980 due to a major shift in overall government policy towards energy use in industry. Partly as a consequence there has been relatively little analysis of this option. It is only now beginning to be widely recognized.

Whether it receives the sustained political support necessary for a major program remains to be seen. The evolution and fate of this option in Brazil is probably the single most interesting aspect to other developing countries of Brazil's development of non-conventional fuels over the next few years.

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TABLE 1 - A VIEW OF THE EVOLUTION OF GASOLINE, ALCOHOL AND DIESEL SUPPLY DEMAND USED TO JUSTIFY THE VEGETABLE OILS PROGRAM (Source Ref 26)

Fuel/Year	(10^6 Cubic Meters) 1981	1982	1983	1984	1985
Gasoline					
- demand	13.3	13.2	13.2	11.9	10.2
- production	14.2	13.8	14.0	13.0	13.6
Ethanol					
- demand	4.0	4.6	5.2	7.3	9.9
- production	4.0	4.6	5.2	7.3	9.9
Diesel					
- demand	19.4	20.8	22.3	23.9	25.7
- production	18.8	20.4	21.8	23.1	23.2
Total petroleum refined	61.8	63.5	64.5	63.5	63.8

TABLE 2 - RECENT PRICE CHANGES FOR FUELS
(Current Cruzeiros)

	Heavy Fuel Oil (kg)	Low Sulfur Fuel Oil (kg)	Diesel (liter)	Gasoline (liter)	Alcohol (liter)
April 1981	18.3	22.8	32.5	66.0	42.0
February 1981	14.6	18.2	26.0	60.0	32.0
December 1980	12.1	15.1	20.0	51.0	27.5
October 1980	10.5	13.1	17.3	45.0	24.7

TABLE 3 - DISTRIBUTION OF CONSUMPTION OF DIESEL OIL BY SECTOR
Brazil - 1975 (ref 38)

Industry	11.5%
Construction	7.4%
Transport (incl. agriculture)	74.8%
Government & public services	7.3%

TABLE 4 - EVOLUTION OF BUS FARES AND DIESEL PRICES - SAO PAULO

	Bus Fares in Sao Paulo (Cruzeiros)	index of Fares	index of Sao Paulo Consumer Prices	Price of Diesel Constant Cruzeiros of (May 1980/liter)	Metro Price of Ticket in Ten Ticket Packet (Cruzeiro)
	6.50	100	100**	--	
May 14, 1980	9.00	138	111	--	
November 1, 1980	13.00	200	157	11.56	
March 4, 1981	15.00	231	196	13.22	11.00
May 10, 1981	20.00*	308***	218***	14.57	17.00

* May was marked by a request for Cr $22 from the bus companies which was refused though they were probably right and by an attempted strike by bus workers, which indicates considerable cost pressure in the industry.

** We use March 980 as a starting point.

*** Projected

Bus and metro fares from Folha de Sao Paulo, May 9, 1981.

TABLE 5 - YIELDS OF SOME VEGETABLE OIL SPECIES

Species	Yield of Oil (t/hectare)[1] (ref 25, p44)	Yield of Oil (t/hectare)[2]	Yield of Oil[3] (t/hectare)
Oil Palm (perennial)	3.00-5.00	--	4.00
Avocado (perennial)	1.30-5.00	--	5.00
Coconut (perennial)	1.30-1.90	--	1.40
Babacu (perennial)	0.10-0.30	--	0.13
Pinhao (perennial)	--	0.39	0.50
Sunflower	0.50-1.90		0.60
Rapeseed	0.50-0.90		0.80
Peanut	0.55-0.75	0.60	0.80
Soybean	0.25-0.35	0.35	0.60
Cotton	0.10-0.20	--	0.20

1) Ref 25, p49, supposedly current yields.
2) Ref 25, p20, actual current yields
3) Ref 27, yields used for projection

TABLE 6 - HARVESTED AREA OF CURRENTLY IMPORT OIL CROPS

	Average Area 1976-78 (Thousand Hectares)
Soybean	7089
Coconut	161
Peanuts	285
Castor Bean	290
Cotton	4819

TABLE 7 - SCALE AND INVESTMENT FOR BIOMASS TECHNOLOGIES IN BRAZIL

	Reference	Scale (Output)	Operating Season (days)	Agricultural Investment (10^6 mid 1980 $)	Industrial Investment (10^6 mid 1980 $)
Peanut Oil	21	60,000 l/d	270	3.85	5.15
Rapeseed Oil	21	60,000 l/d	270	1.10	5.15
Sunflowerseed Oil	21	32,000 l/d	270	1.05	5.15
Soybean Oil	21	26,000 l/d	270	2.45	5.05
Palm Oil	21	43,000 l/d	180	8.50	2.50
Eucalyptus - Charcoal (beehive kiln)	21	78 l/d	330	1.60	1.15
Sugarcane - ethanol (mill)	21	120 m^3/d	150	1.50	9.10
Sugarcane - ethanol (mill)	21	120 m^3/d	210	2.15	9.10
Sugarcane - ethanol (diffuser)	21	120 m^3/d	150	1.45	9.20
Casseva - ethanol	21	120 m^3/d	330	3.45	8.65
Sugarcane - ethanol (mill) year 2000 trend	36	126 m^3/d	200	6.10	11.05
Sugarcane - ethanol (mill) year 2000 advanced	36	194 m^3/d	300	6.90	10.00
Cassava - ethanol	36		330	4.85	11.65

TABLE 8 - COST OF PRODUCING SOME BIOMASS
BASED FUELS PER BARREL OF PETROLEUM PRODUCT SUBSTITUTED

	Reference	Produced Price ($/GJ)	Petroleum Derivitive Substituted	Substitution Factor	Equivalent Substitution Price ($/Barrel)
Peanut Oil	21	$0.632/liter	diesel	.96	$104.70
Rapeseed Oil	21	$0.539/liter	diesel	.96	$ 89.25
Sunflower Seed Oil	21	$0.543/liter	diesel	.96	$ 89.95
Soybean Oil	21	$0.674/liter	diesel	.96	$111.65
Palm Oil	21	$0.402/liter	diesel	.96	$ 66.50
Eucalyptus - Charcoal (beehive Kiln)	21	$0.072/kg	fuel oil	.67	$ 17.10
Sugarcane - Ethanol (mill)	21	$0.30/liter	gasoline	.74	$ 64.45
Sugarcane - Ethanol (mill)	21	$0.273/liter	gasoline	.74	$ 58.65
Sugarcane - Ethanol (diffuser)	21	$0.30/liter	gasoline	.74	$ 64.45
Cassava - ethanol	21	$0.32/liter	gasoline	.74	$ 68.75
Sugarcane - Ethanol (mill) Year 2000 trend	36	$0.25/liter	gasoline	.74	$ 53.70
Sugarcane - ethanol (mill) Year 2000 advanced	36	$0.16/liter	gasoline	.74	$ 34.38
Cassava - ethanol	36	$0.25/liter	gasoline	.74	$ 53.70

Note: Studies assume a 10% discount rate.

TABLE 9 - PRODUCTION QUANTITY ESTIMATED FOR THE PROGRAMME IN THE NEXT TEN YEARS AND BY CULTIVATION TYPE. (MILLIONS OF TONNES) Source Ref 27

OILS / YEARS	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1 - Peanut	0,040	0,140	0,240	0,360	0,520	0,650	0,760	0,860	0,950	1,050
2 - Soya	0,060	0,160	0,300	0,520	0,720	0,870	1,020	1,140	1,200	1,550
3 - Cotton	0,030	0,090	0,160	0,250	0,350	0,410	0,500	0,580	0,650	0,750
4 - Rape	0,040	0,120	0,240	0,380	0,540	0,660	0,800	0,860	0,900	1,000
5 - Sunflower	0,010	0,040	0,060	0,090	0,140	0,190	0,250	0,340	0,400	0,450
6 - Pine Seed	--	--	--	--	--	0,100	0,200	0,390	0,550	0,700
7 - Avocado	--	--	--	--	--	0,100	0,200	0,390	0,550	0,700
8 - Bahia Coconut	--	--	--	--	--	--	0,140	0,320	0,800	1,050
9 - Dende	--	--	--	--	--	--	--	--	0,150	0,300
10 - Babassu	--	--	--	--	--	--	--	0,140	0,250	0,450
TOTAL	0,180	0,550	1,000	1,600	2,270	2,980	3,870	5,020	6,400	8,000

TABLE 10 - CHRONOGRAM FOR THE AREAS DESTINED FOR OIL BEARING PLANT CULTIVATIONS - BRAZIL 1981 - 1990 SCALE: 10^3 HECTARES (Source Ref 27)

OILS \ YEARS	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1 - Peanut	50	175	300	375	542	677	792	717	792	875
2 - Soya	100	267	500	722	1000	1208	1417	1267	1333	1722
3 - Cotton	150	450	800	1042	1459	1708	2083	1933	2167	2500
4 - Rape	50	150	300	396	562	687	833	717	750	833
5 - Sunflower	17	67	100	125	194	264	347	378	444	500
6 - Pine	--	--	--	--	--	268	571	780	1100	1400
7 - Avocado	--	--	--	--	--	29	57	78	110	140
8 - Bahia Coconut	--	--	--	--	--	--	100	229	571	750
9 - Dende	--	--	--	--	--	--	--	--	37	75
10 - Babassu	--	--	--	--	--	--	--	1077	1923	3461
TOTAL	367	1109	2000	2660	3757	4859	6200	7176	9227	12256

TABLE 11 - ESTIMATED COST REDUCTIONS DUE TO SUBSIDIES IN FINANCING, 1980
(Source Ref. 21)

	Cost at 10%[1] discounted cash flow	Cost with[1] Subsidies	Percent Reduction due to Subsidies
Sugarcane-ethanol (mill 120,000 liters per day, 150 days/year)	15.45/liter	10.10 liter	35%
Cassava-ethanol (120,000 liters per day, 330 days per year)	16.24/liter	10.89/liter	33%
Eucalyptus-charcoal	3.67/kg	2.28/kg	38%

Notes: 1) Cruzeiros of May 1980.

TABLE 12 - ESTIMATES OF SUBSTITUTION VALUE OF ETHANOL FOR GASOLINE

	Amount of Gasoline Substituted by One Liter of Ethanol (Liter)	Relative Efficiency (Alcohol/Gasoline) (%)
Gasoline-IPT (Ref 21)	0.74[3]	120
IBRD (Ref 20)	0.83[2]	135
(Ref 35)	.76[2) 4)]	123
Paulo Penido Filho (Ref 19)	--	126

Notes:
1) Assuming anhydrous alcohol
2) Assuming hydrated
3) It is not known what the IPT figure assumes, but given the thrust of the work it is probably for hydrated ethanol.
4) In Reference 35 also not specified however the only way that the volume an energy content figures in Figure 6 harmonize is to assume that the higher heating value of anhydrous ethanol was used.
5) Assumes compression ratio of 12 for alcohol engine and 8 for gasoline. This is currently an upper bound since most Brazilian alcohol cars have compression ratios of 10.5-11.

TABLE 13 - PRODUCTION AND GOALS FOR ALCOHOL PRODUCTION

	(A) Production Actual	(B) Goal For Production	(C) Domestic Consumption Total	(D) Alcohol Anhydrous Fuel	(E)	(F) Alcohol Hydrated	(G)	(H) Chemicals	(I) Expo
1977	1010	--	1006	639		--		367	4
1978	1500	--	1500	1145		--		355	0
1979	2400	--	2300	2100		Small		200	87
1980	(3400)	3800	3400	2900	(2460)	200	(1040)	300	(27
1981	(4100)	4700	4700	3000	(2590)	1100	(2010)	600	
1982	--	5500	5500	2900	(2390)	1800	(2710)	800	
1983	--	6700	6700	2900	(2250)	2800	(4725)	1000	
1984	--	8500	8500	2800	(2240)	4500	(5860)	1200	
1985	--	10,700	10,700	2700	(2250)	6500	(6950)	1500	

Notes: Up through 1979 figures in columes A, C, D, F, H and I are for actual production and consumption (Ref 20, pp 7,8). After this we get a mixture of different projections and results. Column (A) shows the results for 1980 and 1981. (B) represents the original set of goals for the program (available from many sources, in this case taken from (Ref 20, 22, and 24). (C, D, F, H) are the domestic consumption goals after 1979 given in Ref 20: The total (C) is slightly lower in 1980 than the production goal and probably represents a mid-year retraction after the smaller production was known.

(E and G) were obtained in Ref 24 and were projections by Petrobras, with the 1980 figures very close to reality.

Column I (exports) shows estimated actual exports in 1980 (Ref 22). No exports were formally incorporated into the goals of the program. Exports in 1980 appear to have been due to weak demand for alcohol in first half of 1980 due to slow acceptance of alcohol cars.

TABLE 14 - NATIONAL ALCOHOL PROGRAM PROJECTS
APPROVED BY CENAL ON 29 SEPTEMBER 1980

Producing Region	Annexed Distilleries		Automotive Distilleries		Total
	Number	Increased Capacity (Million liters per harvest)	Number	Increased Capacity (Million Liters per harvest)	Increased Capacity (Million liters) per harvest)
North/Northwest	56	787.7	48	1420.3	2208.0
Central/South	110	1991.0	89	1913.6	3904.6
Total Brazil	166	1778.7	137	3333.9	6112.6

TABLE 15 - NATIONAL ALCOHOL PROGRAM PROJECTS
APPROVED BY CENAL ON 1 APRIL 1981

Producing Region	Annexed Distilleries		Automotive Distilleries		Total	
	Number	Increased Capacity (Million liters per harvest)	Number	Increased Capacity (Million Liters per harvest)	Number	Increased Capacity (million liter per harvest
North/Northwest	59	844.3	62	1714.4	121	2558.7
Central/South	122	2374.6	136	2884.8	258	5259.5
Total Brazil	181	3218.9	198	4599.3	379	7818.2

Note: Of the 379 projects approved, at least 54 are encountering serious legal problems in finalizing contracts with credit institutions. These problems run from ownership of the land to proof of adequate financial resources in the enterprise. Analysis suggests that in 1985 only 6.8 billion liters can be produced by projects approved by April 1 because of lag time in reaching full production.

(Source: Estado de Sao Paulo, May 16, 1981)

TABLE 16 - PRELIMINARY ESTIMATE OF COST OF SUBSTITUTING FOR ONE BARREL OF PETROLEUM DERIVITIVE
(Fuel Oil by Charcoal, Gasoline by Ethanol)

	Charcoal/Fuel Oil Option	Ethanol/Gasoline Option
Cost of production per barrel[1)] of derivitive for which substitution is made	$17.10	$60.00
Cost of transport to user[2)] per barrel substituted	$11.40	$ 4.10
Increased Cost to User per barrel[3)] Substituted	$ 4.00	$ 1.60
Total	$32.50	$65.70

1) From Table 8 (IPT)
2) Assumes 6¢ per ton-km, with charcoal transported 800 Km and ethanol 400 Km. Substitution coefficients as in Table 8 (IPT). Cost per ton-km from ref 11.
3) Cost for charcoal derived from increased capital costs (with 10% discount rate) and operating costs for a charcoal boiler based on ref 11. This cost has been increased 60% to account for smaller boilers. Ethanol based on an increased automobile cost of $150 (ref 20) with 2000 Liters of ethanol per year and an annual capital charge of 10%. Substitution coefficients from table 8 (IPT).

TABLE 17 - PROJECTION OF WOOD SUPPLY FROM NATURAL FOREST
BY REGION AND FOREST TYPE (Source Referance 29)

		(A) Total Forested Area	(B) Area In Use	(C) Available Volume Of Wood From (B)	(D) Volume to Be Removed ($10^6 m^3$) Industrial Wood	(E) Fire wood	(F) Total	(G) Area Of Forest Cleared	(H) Volume of Wood From Cleared Forest	(I) Volume From (H) Which Can Be Recovered	(J) Total Supply Of Wood (I&F)
Dense Forest											
North	1980	279.5	0.9	157.5	6.1	4.6	10.7	1.1	193	6.8	17.5
	1985	273.5	1.2	210.0	11.8	6.1	17.9	1.2	210	8.4	26.3
Northeast	1980	11.7	0.3	40.5	1.5	4.6	6.1	0.24	32.4	3.9	9.7
	1985	10.6	0.4	54.0	2.3	1.4	3.7	0.22	29.7	4.2	10.4
Southeast	1980	6.1	0.5	65.0	9.1	--	9.1	0.28	36.4	9.1	18.2
	1985	4.8	0.4	52.0	8.5	--	8.5	0.26	33.8	10.1	18.6
South	1980	4.6	0.5	82.5	11.0	7.9	18.9	0.24	34.8	10.4	29.3
	1985	3.5	0.6	99.0	13.2	3.0	16.2	0.22	31.9	11.2	27.4
Center-West	1980	29.9	0.5	82.5	2.3	9.3	11.6	0.28	46.5	2.3	13.9
	1985	25.5	0.6	99.0	3.3	9.1	12.4	0.26	42.9	2.6	15.0
Cerrado											
North	1980	33.9	0.1	5.5	--	--	0.9	0.08	4.4	0.2	1.1
	1985	33.5	0.1	5.5	--	--	1.1	0.08	4.4	0.2	1.3
Northeast	1980	30.4	2.6	54.6	--	--	24.1	0.4	8.4	3.4	27.5
	1985	28.4	2.4	50.4	--	--	22.3	0.4	8.4	3.8	26.1
Southeast	1980	8.8	0.7	18.2	--	--	13.7	0.4	10.4	7.3	21.0
	1985	7.2	0.5	13.0	--	--	10.8	0.32	8.3	5.8	16.6
Center-West	1980	36.3	3.6	180.0	--	--	55.4	0.42	21.0	7.4	62.8
	1985	34.4	4.3	215.0	--	--	53.5	0.38	19.0	7.6	61.1
Caatinga											
Northeast	1980	29.2	8.0	80.0	--	--	17.6	0.46	4.6	1.6	19.2
	1985	27.1	7.5	75.0	--	--	16.1	0.42	4.2	1.7	17.8
Southeast	1980	1.7	0.7	7.0	--	--	2.7	0.04	0.4	0.2	2.9
	1985	1.5	0.7	7.0	--	--	2.6	0.04	0.4	0.2	2.8
Dense Forest-											
Brazil	1980	331.8									88.6
	1985	317.9						2.14			97.7
Cerrado-Brazil	1980	109.4									112.4
	1985	103.5									105.1
Caatinga-Brazil	1980	30.9									22.1
	1985	28.6									20.6
Total											
Brazil	1980	472.1	--	773.3	30.0	140.8	170.8	3.94	392.3	52.6	223.1
	1985	450.0			39.1						233.4

TABLE 18 - PROJECTION OF DEMAND FOR WOOD BY REGION AND PRODUCT
(Source Reference 19, Case 2:1)

(Millions of Cubic Meters of Roundwood Equivalent)

	Northeast		Southeast		South		Central-West		Brazil	
	1980	1985	1980	1985	1980	1985	1980	1985	1980	1985
Firewood	61.7	62.8	45.9	46.7	24.8	26.1	10.2	11.3	149.9	154.7
Charcoal	--	--	39.0	44.8	--	0.3	--	--	39.0	45.1
Sawnwood	2.4	3.3	12.5	17.3	3.6	5.1	0.9	1.3	19.9	27.6
Laminated Products	0.2	0.3	2.0	3.1	0.5	0.8	0.1	0.2	2.9	4.4
Particleboard	0.1	0.1	1.0	1.6	0.2	0.3	--	0.1	1.3	2.1
Fibreboard	0.1	0.1	0.7	1.1	0.2	0.3	--	0.1	1.1	1.6
Pulp-Short Fibre	0.4	0.5	3.1	4.6	0.8	1.1	0.2	0.3	4.4	6.7
Long Fibre	0.5	0.6	2.2	3.0	0.7	0.9	0.2	0.2	3.6	4.9
Newsprint	0.4	0.5	1.2	1.6	0.4	0.5	0.1	0.2	2.1	2.8
Writing Paper	0.4	0.5	2.8	4.0	0.7	1.0	0.2	0.2	4.0	6.0
Packaging	0.7	1.0	4.2	6.1	1.1	1.7	0.3	0.4	6.5	9.3
Industrial Paper	0.2	0.4	2.8	4.5	0.6	1.0	0.1	0.2	3.9	6.1
Other Industrial Wrap	0.5	0.7	3.3	4.8	0.9	1.3	0.2	0.3	5.1	7.3
Total	67.6	71.0	120.7	143.2	34.5	40.4	12.5	14.8	243.7	278.6
Subtotals										
Industrial Wood	5.9	8.2	35.8	51.7	9.7	14.0	2.3	3.5	54.8	78.8
Fuelwood	61.7	62.8	84.9	91.5	24.8	26.4	10.2	11.3	188.9	199.8

TABLE 19 - ESTIMATED BALANCE OF SUPPLY OF NATIVE WOOD AND DEMAND BY REGION 1980 AND 1985

All Figures in Millions of Cubic Meters (Solid) Of Roundwood Equivalent

	Northeast	Southeast	South	Central-West	Brazil
Industrial Wood					
Supply 1980	1.5	9.1	11.0	2.3	30.0
Demand 1980	5.9	35.8	9.7	2.3	54.8
Net Balance	-4.4	-26.7	+1.3	0	-24.8
Supply 1985	2.3	8.5	13.2	3.3	39.1
Demand 1985	8.2	51.7	14.0	3.5	78.8
Net Balance	-5.9	-43.2	-0.8	0.2	39.7
Fuelwood					
Supply 1980	55.2	33.0	18.3	74.4	193.1
Demand 1980	61.7	84.9	24.8	10.2	188.9
Net Balance	-6.5	-51.9	-6.5	+64.2	+4.2
Supply 1985	49.5	29.5	14.2	72.8	199.3
Demand 1985	62.8	91.5	26.4	11.3	199.8
Net Balance	-13.3	-62.0	-12.2	+61.5	-0.5

Notes: Based on Tables 17 and 18. Industrial wood supply based on column D of Table 17. All other wood is assumed to be only fuelwood (including all wood supply in column I of Table 17 from cleared forest.

On the demand side, fuelwood includes firewood and wood for charcoal production.

TABLE 20 - GROSS AND NET AVAILABILITY OF WOOD AS ESTIMATED BY IBDF
(Based on Table 17)

All Figures in Millions of Cubic Meters (Solid)
Of Roundwood Equivalent

	A Volume Of Wood In Area In Harvest in 1980	B Volume Assumed Removed	C Volume of Wood Wood In Cleared Forest Land	D Volume Assumed To be Removed	E A-B	F C-D	G E&F
North	163.0	11.6	197.4	7.0	151.4	190.4	341.8
Northeast	175.1	47.8	45.4	8.9	127.3	36.5	163.8
Southeast	90.2	25.5	47.2	16.6	64.7	30.6	95.3
South	82.5	18.9	34.8	10.4	63.6	24.4	88.0
Center-West	262.5	67.0	67.5	9.7	195.5	57.8	253.3
Brazil	773.3	170.8	392.3	52.6	602.5	339.7	942.2
Subtotal (South, Southeast, and Central-West)	435.2	111.4	149.5	36.7	323.8	112.8	436.6

TABLE 21 - ESTIMATES OF THE GROWTH IN FUEL OIL CONSUMPTION IN MAJOR CONSUMING INDUSTRIES (WITHOUT SUBSTITUTION) (10^6 per year) (Source: Reference 30)

	1980	1981	1982	1983	1984	1985
Cement	2.8	2.9	3.2	3.5	3.8	4.2
Iron and Steel	1.6	1.6	1.6	1.8	2.0	2.1
Paper and Pulp	1.4	1.5	1.6	1.7	1.8	1.9
Ceramic	1.3	1.4	1.4	1.4	1.4	1.5
Food and Drink	1.6	1.7	1.8	1.9	2.0	2.1
Textiles	0.7	0.8	0.9	0.9	1.0	1.1
Total of Listed Industries	9.4	9.9	10.5	11.2	12.0	12.8

Note: Fuel oil with a specific gravity of 0.92 and with 159 liters per barrel. To convert tons per year to barrels per day multiply by 0.0187. The 1980 estimate of 9.4 million tons is equivalent to 176.000 barrels per day, rising to 239,000 in 1985.

TABLE 22 - POTENTIAL WOOD DEMAND 1980 AND 1985
(Source Reference 30)

	1980 (10^6t)	1985 (10^6t)
Wood requirements for:		
Charcoal for Iron and Steel production	21.8	25.2
Paper and Pulp	8.2	11.1
Processed wood	12.2	13.7
Fuelwood (Traditional market)	82.4	85.0
Wood for Fuel Oil Substitution	3.5	31.1
Total Wood	128.1	166.1

TABLE 23 - ESTIMATE OF AVAILABILITY OF PLANTED WOOD
FOR EXISTING INDUSTRIAL USES (FROM ALREADY PLANTED FORESTS)
(Source Ref. 30)

	1980 (10^6t)	1985 (10^6t)
Iron and Steel Industry	3.8	11.9
Paper and Pulp	8.2	11.1
Processed Wood	13.3	13.3
Subtotal	25.3	36.3
Forest Residues which might be collected from these plantations	3.7	5.5
Total From Existing Planted Forest	29.0	41.8
Total Which must be supplied From Natural Forests	99.1	124.3

TABLE 24 - AREAS FOR FOREST PLANTING INDICATED FOR IRON AND STEEL PRODUCTION, PAPER AND PULP AND PROCESSED WOOD IN COMPARISON WITH PLANTING CAPACITY OF REFORESTATON INDUSTRY AS ESTIMATED IN 1979.
(Source Ref. 30)

All Figures in Thousands of Hectares

	Iron and Steel	Paper and Pulp		Processed Wood		Total		Total Reforestation Capacity
	Eucalyptus	Eucalyptus	Pinus	Eucalyptus	Pinus	Euc.	Pinus	
1980	130	50	90	20	80	200	130	500
1981	131	50	50	20	80	201	130	600
1982	131	60	60	20	80	211	140	720
1983	144	60	60	20	80	224	140	860
1984	128	70	80	20	80	218	160	1040
1985	122	70	80	20	80	212	160	1250

TABLE 25 - DEMAND FOR IMPORTED SEED GENERATED BY MAXIMUM POSSIBLE EXPANSION OF EUCALYPTUS AND MAXIMUM EXPANSION OF DOMESTIC SEED PRODUCTION AS ESTIMATED OF 1979

	Maximum Area[1)] To Be Planted by Eucalyptus (10^3 hectares)	Area Which [2] Could be Planted For Energy (10^3 hectares)	Total Demand[3] For Seeds (kg)	Rate at Which Domestic Seeds Could be Produced (kg)	Import Requirements For Seed (kg) (Rate assumed in Source)	Adjusted Import Rate
1980	370	170	14,800	3,600	11,200	24,150
1981	470	269	18,800	3,960	14,480	31,290
1982	580	369	23,200	7,400	15,800	36,100
1983	720	496	28,800	13,600	15,200	40,400
1984	880	662	35,200	25,100	10,100	40,900
1985	1090	878	42,000	43,600	0	38,150

1) Source ref 30
2) Residual of total capacity and other needs in Table 24
3) Assumes 40 g per hectare, in fact Brazil in 1978/79 was consuming 75 g per hectare (ref 30, p 113)
4) Adjusted import rate based on 75 g per hectare less domestic production.

TABLE 26 - ESTIMATE (1979 VINTAGE) OF OIL SUBSTITUTION POTENTIAL IN FIVE INDUSTRIES IN 1985

Industry	Oil Consumed	Oil Assumed To Be Substituted (1000 t)	Charcoal Consumed (1000 t)	Wood Equiv. of Charcoal (1000 t)	Direct Use Of Wood (1000 t)	Total (1000 t)
Paper and Pulp	1,900	1330	--	--	5590	5590
Cement	4,210	2275	3290	13,160	--	13,160
Ceramic	1,500	750	800	3,200	1000	4200
Food Processing	2,100	1005	1100	4,400	1300	5700
Textile	1,100	550	400	1,600	800	2400
Total	10,800	5910	5590	22,360	8690	31,050

Note: Estimates synthesized from Table 21 and ref 30 pp 02, 104, 139-166. The moisture content of the wood is not specified. Since ref 30 later converts a cubic meter (solid) to weight with a multiplication factor of 0.55 it is probably on an oven-dry basis.

TABLE 27 - ESTIMATED COST OF CHARCOAL FROM NATIVE FOREST
(Source: Reference 10)

		Cost per m^3 Of Charcoal (Cruzeiro August 1980)	Cost per m^3 Of Charcoal (dollars of August 1980)
a) Cutting wood (2 man-hrs/stere)		185.9	
b) Transport of wood to kilns (0.64 man-hrs/stere)		59.4	
c) Carbonization (4 man-hrs/m^3 charcoal		123.9	
d) Truck-loading (1.03 man-hrs/m^3 charcoal)		31.8	
e) Depreciation of structures and services		82.6	
f) Expenses of transport of personnel, and spare parts (20% a-e)		96.9	
g) Stumpage (25% of a-e)		121.0	
h) Administration		70.2	
i) Profit		70.2	
Subtotal - charcoal loaded on truck at kilns:		841.9	15.14
k) Transport at 5.5¢/km and $4m^3$/ton	400 km	305.8	5.50
	600 km	458.7	8.25
	800 km	611.6	11.00
	1000 km	764.5	13.75
Total cost, cif user	1200 km	917.4	16.50
Total cost, cif user transport distance	400 km	1148	20.65
	600 km	1301	23.40
	800 km	1454	26.15
	1000 km	1606	28.90
	1200 km	1759	31.65

Note: 1) Wood is assumed to be converted to charcoal at a rate of 3 stere per m^3 of charcoal. Figures are originally for August 1978 inflated wth the standard price index (Conjuntura Column 2).

Figure 1: Price of Petroleum Derivatives in Brazil
(U.S ¢/liter except fuel oil per kg)

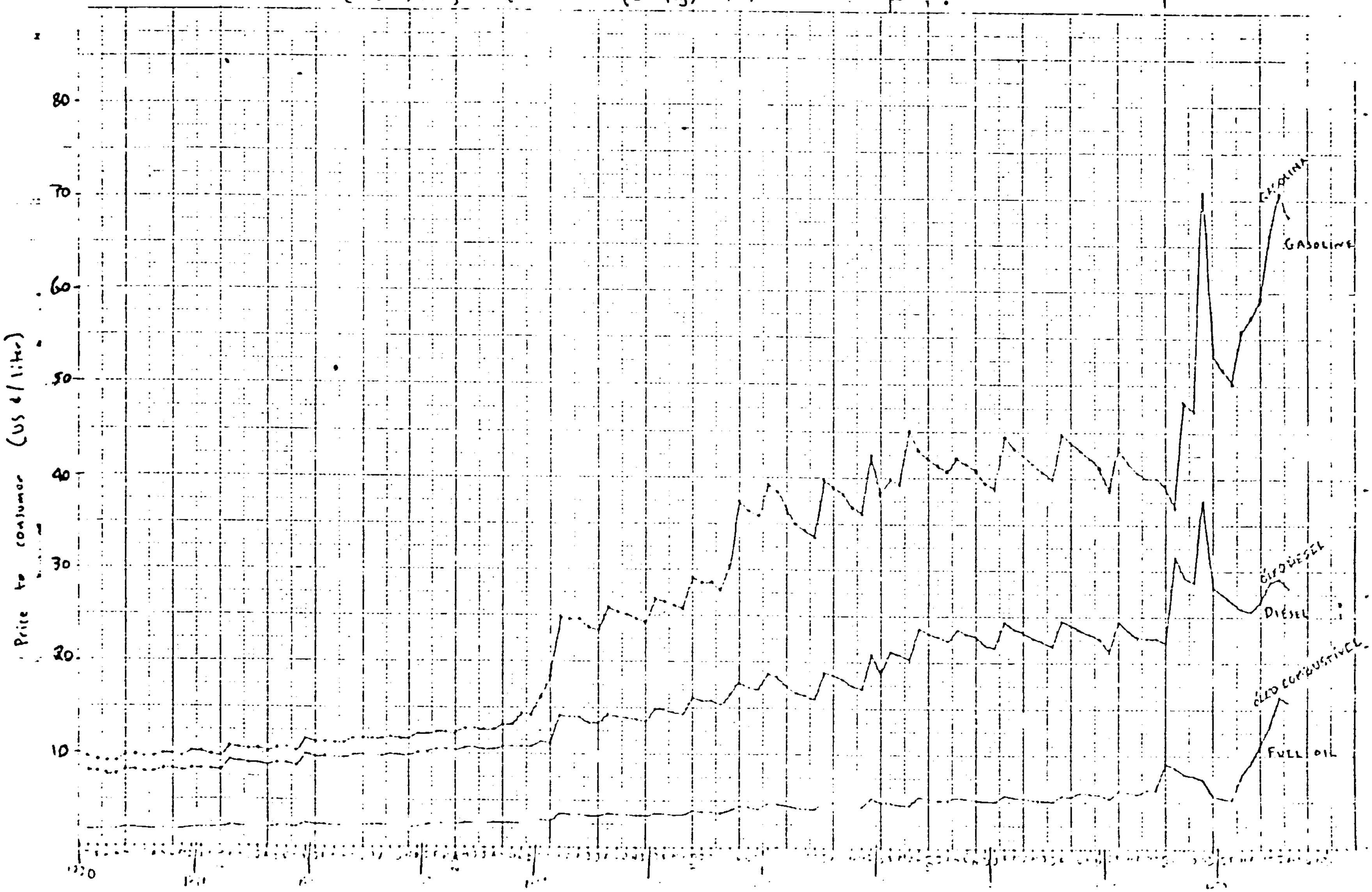
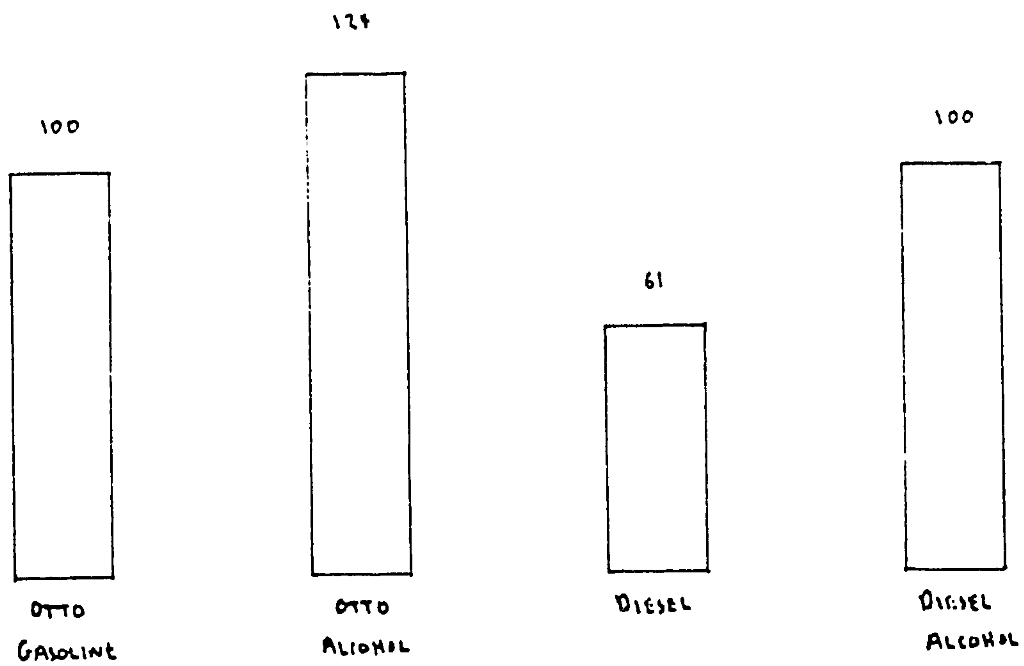


FIGURE 2 A: VOLUME OF FUEL REQUIRED PER TON-KILOMETER



B. ENERGY REQUIRED PER TON-KILOMETER

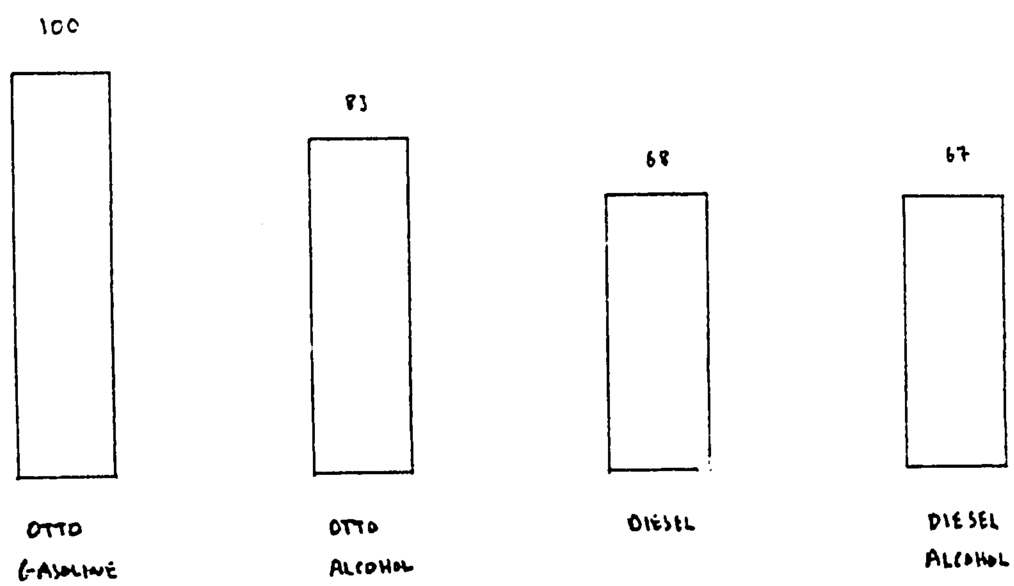
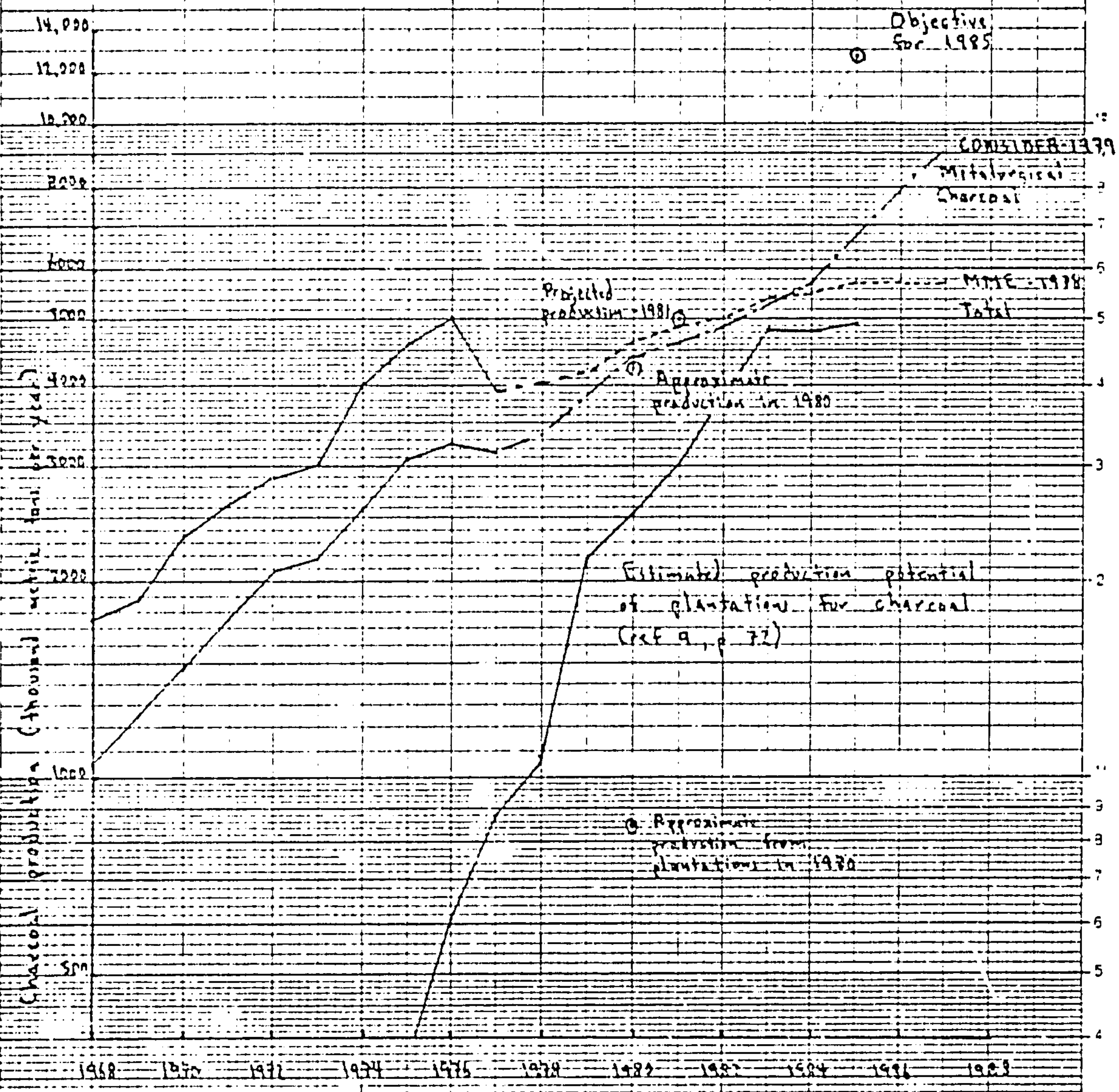


FIGURE 3 : PRODUCTION ESTIMATES AND PROJECTIONS FOR CHARCOAL IN BRAZIL 1968-88



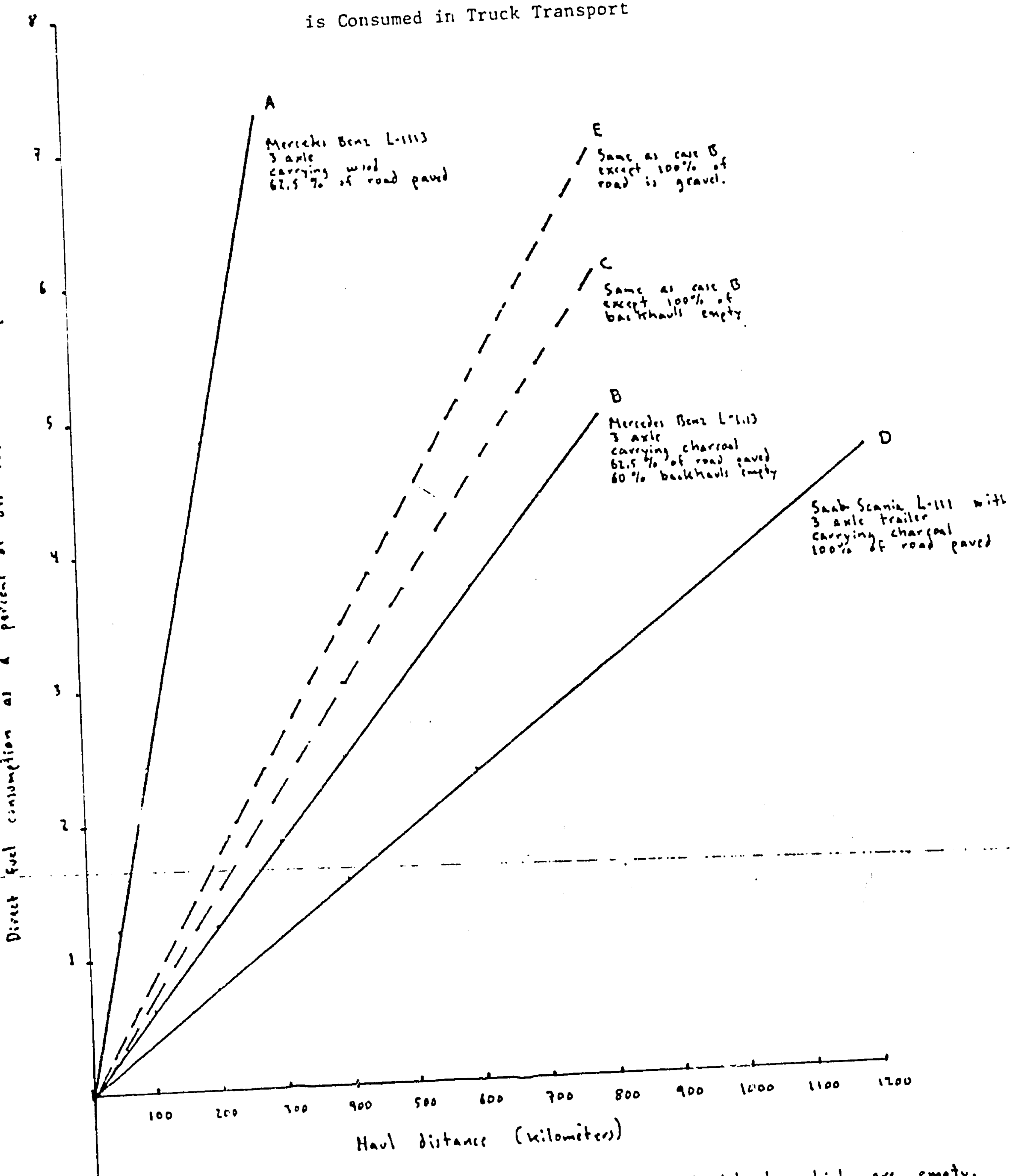
Notes: a) 1980, 81 and 85 points from ref 5 and 5

b) CONSIDER-1979 assumes 3.9 m^3 of charcoal per ton of pig iron, and 4 m^3 per ton of charcoal

c) MME-1978 and CONSIDER-1979 material for basic projection cited in ref 8

FIGURE 4

Proportion of Energy Substitution Capability which is Consumed in Truck Transport



Note: Energy consumption includes fuel consumed on 60% of backhauls which are empty, except case C where 100% of backhauls are empty.

FIGURE 5: PRODUCTION OF DIESEL ENGINES IN NON-COMMUNIST WORLD