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A CENTRALIZED "SOFT" ENERGY PATH

by

Prof. José Goldemberg

University of São Paulo
São Paulo, Brazil

UNIVERSIDADE DE SÃO PAULO
INSTITUTO DE FÍSICA
Caixa Postal - 20.516
Cidade Universitária
São Paulo - BRASIL

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I. INTRODUCTION

As is well known, Brazil has embarked on a large program of substitution of petroleum derivatives by ethanol produced from sugar cane. The first goal of this program was to add 20% alcohol to gasoline in a mixture branded "gasohol" which does not require modification of conventional motors. This goal was rapidly achieved in the period 1977-1979 by increasing the yearly production of alcohol from 500 to 3,500 million liters (60,000 barrels per day).

The next step is to convert motors to run on pure (or almost pure) ethanol, a step that required an important decision on the part of car manufacturers in Brazil; this decision was taken in the beginning of 1980 and a significant part of the cars manufactured this year will be produced with modified motors - 200.000 cars in a total of 1 million. The modification is basically a change in compression ratio from 1:6 (for gasoline) to 1:12 (for pure alcohol).

As a consequence vast quantities of ethanol will be needed to supply the automobile fleet which by 1985 will be almost totally converted to alcohol (approximately 10 million cars). Firm plans have been laid to produce 10.7 billion liters of alcohol in 1985. This will correspond to approximately 50% of the projected gasoline consumption in that year had not the alcohol program existed. This amount corresponds to 200,000 barrels per day (bpd) of alcohol, a sizable amount of liquid fuel by any standards. The total consumption of petroleum in Brazil is 1,000,000 bpd.

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Efforts are being made to introduce ethanol in Diesel motors and eventually as a replacement for fuel oil, reducing therefore the amount of imported oil.

The use of ethanol as a substitute for petroleum is an interesting solution for the energy crisis and what we will do here is to discuss the potential for and some constraints of such solution, namely:

a. Is this intrinsically a centralized or decentralized type of solution?
b. How applicable is this solution throughout the Third World?
c. What are the conflicts with social and environmental goals?

II. CENTRALIZED "versus" DECENTRALIZED SOLUTIONS

One way to decide if a given energy source is suited for a decentralized solution is to compare its energy density (in watts/m^2, for example) to the consumption energy density of the people it is supposed to supply.

For example, in most parts of the Third World the yearly average incident solar energy is at least 100 watts/m^2; since the efficiency for capturing this power is not higher than 1%, in most cases, one has an available energy density from the sun of roughly 1 watt/m^2.

Table 1 gives energy densities for a number of renewable energy sources.

place Table 1 near here

The energy consumption density of urban population is of the order of 5 watts/m^2. For example the city of London with 1,100 inhabitants/km^2 has an average consumption of 5 kw/capita; the energy consumption density (per square meter) is the product of these two numbers, i.e. 5.5 watts/m^2. It is obvious therefore that to supply the energy needs of the population of London from any of the sources of solar

TABLE 1

Energy Densities for Renewable Energy Sources

Source	watts/m^2
Fuelwood (natural forests)	~ 0.03
Fuelwood (planted forests)	~ 0.3
Biogas	~ 0.1
Hydropower	~ 0.1-0,003
Wind (weak)	~ 0.4
Wind (strong)	~ 7.0
Ethanol from sugarcane	~ 0.4
Solar direct (heat)	~ 10.0
Solar direct (electricity)	~ 1.0

renewable energy listed in Table 1 would be very difficult indeed because of the large areas needed (except may be for hot water). The same is true for most urban areas as can be seen in Table 2.

place Table 2 near here

This is not the case of rural areas in the Third World where the population density is much lower and the energy consumption is also very low. In the case of India for example the energy consumption density is 0,04 watts/m^2 which can easily be supplied by any of the sources listed in Table 1.

To supply the energy needed in urban areas one has therefore either to use fossil fuels or to collect the solar energy from vast areas of land and transport it to cities. This is precisely what is done in hydroelectric generating stations where hundreds of kilometers of land are covered by water in suitably located reservoirs and the energy generated is transported to cities in the form of high energy density electric power.

This might seem a cumbersome method for supplying the energy needs of urban populations but it is the method used since the most remote antiquity to feed people in cities. The density of agricultural products is also very low - less than 1 kg of cereal per square meter of land per year - and the only method of solving the problem of food supply in cities is by cultivating large extensions of land, collecting the foodstuff and transporting it to the consuming centers.

Table 3 shows typical yearly productivities of some agricultural products in Brazil.

place Table 3 near here

Under brazilian conditions it is necessary to use 1 hectare of land (10,000 sq. m) to supply the food neces-

TABLE 2

Urban and Rural Densities

Country and State	Population Density (people/km^2)		Energy Consumption (kcal/capita/day)		Energy Consumption Density watt/m^2	
	Urban	Rural	Urban	Rural	Urban	Rural
INDIA	6,000	135	41,600	7,200	12	0.04
LONDON	1,100	-	108,000	-	5.7	-
TOKYO	980	-	81,000	-	3.8	-
S.PAULO (Brazil)	1,260	13	50,000	9,600	3.2	0.006

1 kw of installed power corresponds to a consumption of 20,800 kcal/day.

TABLE 3

Yearly Agricultural Productivity in Brazil

Crop	Yield (kg/m^2)
Rice (with irrigation)	0,2 - 0,4
Rice (without irrigation)	0,1 - 0,2
Black beans	0,08 - 0,15
Soyabeans	0,15 - 0,2
Corn	0,15 - 0,3
Wheat (with irrigation)	0,1 - 0,25
Wheat (without irrigation)	0,08 - 0,2
Coffee	0,15 - 0,2

sary to feed an average family (5 persons) which consumes approximately 1 ton of cereals per year.

It is very interesting to notice - again under brazilian conditions - that an average family in the city of São Paulo requires 2 kw of power for transportation (mainly in automobiles). This amount of power can be obtained from 1 ha of land if one produces ethanol from sugar cane, as can be seen from Table 1.

One concludes therefore that ethanol from sugarcane can solve the transportation energy needs of urban areas by "harvesting" ethanol from large extensions of land; this however requires sophisticated mechanized systems of planting , harvesting and industrial processing which are characteristic of "centralized" technologies.

In addition to the agricultural problems involved in growing sugarcane with high yields (by the use of irrigation and fertilizer) there is an industrial phase in which the sugarcane juice is extracted, fermented and the ethanol is extracted by distillation. A block diagram of these operations is shown in Figure 1.

place Figure 1 near here

After considerable experience one has found out that the minimum size, from a technical and economical viewpoint, for industrial units is 20,000 liters per day; this corresponds to the harvesting of approximately 1,000 ha of a sugarcane plantation per year. In general 5 or 6 of these units are installed together with some basic common parts of the machinery in so called distilleries capable of producing 100,000 liters per day. Much smaller units can be built but they have low efficiencies and do not benefit from economies of scale; therefore the price of the ethanol produced is prohibitively high. The technologies needed for competitive small scale production might however still be developed.

With present technology, the production of large quantities of ethanol involves centralized facilities (including storage and distribution), although in a scale smaller than petroleum refineries which typically process 50,000 bpd (8 million liters per day). Typical investments in the industrial phase are US$ 15,000 for one barrel per day of alcohol produced; this compares very well with US$ 40,000 per barrel per day for the fabrication of synfuel from coal, which is being actively considered in the United States.

This is typically a renewable energy source and therefore with many characteristics of being a "soft path" solution but which requires a "centralized" approach.

III. POTENTIAL FOR ETHANOL PRODUCTION IN THE THIRD WORLD

In Brazil, ethanol is being produced almost exclusively from sugarcane which is a traditional culture in the country that requires good land and fertilizer.

The average yield of sugarcane is 50 tons per hectare/ year; from each ton one can produce either 100 kg of sugar or 70 liters of alcohol, i.e. 3,500 liters of alcohol per hectare/ year.

Presently 1 million hectares are being used for this purpose (in addition to sugar production which takes another 1.5 million hectares) displacing other crops which might be more important to feed the population of the country. This is actually one of the serious problems of the ethanol program in Brazil; we will come back to this point in Section IV.

The goal to reach a production of 10.7 billion liters of alcohol in 1985 will require 3.5 million hectares which is an appreciable fraction of the total presently arable area of the country (8% of a total of approximately 40 million ha) being used as can be seen in Table 4.

In order to find out what the worldwide possibilities of this method of producing energy are one can enquire what the most important world sugar producers are, to find out if they could follow the path taken by Brazil, i.e. divert sugar production to ethanol production in a significant way.

place Table 4 near here

Table 5 lists 15 countries which account for approximately 80% of the world production of sugar cane.

place Table 5 near here

Approximately 40% of the sugarcane raw material is used for ethanol production in Brazil as stated before. This corresponds to 60,000 barrels per day (6% of total liquid fuel consumption of the country), produced on 2.5% of the total arable and permanent cropland of the country.

Brazil produces only 20% of the total sugar cane production of the countries listed in Table 5 covering 6% of its arable land with such crop. The average of the arable land of the countries listed in Table 5 is 2.2%.

If all the other countries listed in Table 5 were to follow the example of Brazil (and used 40% of their total sugarcane production to produce ethanol) the total production of ethanol would amount to 300,000 bpd which is approximately 5% of the total daily consumption of liquid fuels of 6 million bpd in the non-OPEC countries of the Third World. If the area covered by sugarcane were to increase from the present average of 2.2% to 6% the production would increase to 15% of present consumption in non - OPEC Third World countries, which is an appreciable amount.

The raw material resource basis for the production of ethanol could however be significantly expanded if ethanol could be produced from celulosic materials. There seems to be no question that the necessary technology is available although there are not yet industrial installations in Third World countries following this route.

The situation however will change rapidly in the near future in Brazil because this country is embarking

TABLE 4

Land Utilization in Brazil, 1977

(x 10^3 Hectares)

Total Area [a]	851,197
Land Area [b]	845,651
Arable Land and Permanent Crop [c]	40,720
Permanent Meadows and Pastures [d]	509,000
Forest and Woodland [e]	166,000
Other Land [f]	129,931

Source: 1978 FAO Production Yearbook - "Food and Agricultural Organization (FAO) of the U.N.", Rome, Italy, Vol. 32 (1979).

[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 5

Sugar Cane Production

	Area used x 10^3 ha	Production x 10^3 ton	Total arable and permanent cropland (x 10^3 ha)	Fraction of cropland occupied by sugarcane (%)
India	3,220	181,628	169,400	1.9
Brazil	2,413	129,223	40,720	5.9
Cuba	1,246	66,400	3,150	40.0
China	675	47,137	106,500	0.6
Mexico	480	34,500	23,220	1.9
Pakistan	823	30,077	20,300	4.0
Colombia	290	23,100	5,505	5.2
Australia	258	21,500	44,900	0.6
Philipines	503	20,838	8,100	6.2
South Africa	250	19,500	14,560	1.7
Thailand	567	19,000	17,650	3.2
Indonesia	180	15,000	17,200	1.0
Argentina	346	14,600	35,000	1.0
Dominican Rep.	174	10,850	1,230	1.4
Bangladesh	150	6,700	9,125	1.6
	11,575	640,053	516,560	2.2 (Average)

Source: 1978 FAO Production Yearbook - "Food and Agricultural Organization (FAO) of the UN. Rome, Italy, vol. 32 (1978)

*The yield changes from country to country; for this reason the numbers in the second column are not strictly proportional to the ones in the first column. Yield may change from 50 to 90 tons/ha.

in an ambitious program of producing ethanol from wood to supplement the production from sugarcane using the experience obtained in this field during the Second World War in Germany, Switzerland, the Soviet Union and the United States.

The sustainable forest yield (above ground annual increment) is generally taken as 8 oven dry tons (odt) per ha/year although higher yields of 20 odt/ha/year are quite common in managed forests. Taking 14 odt/ha/year as an average one can assume that 2100-2800 liters of ethanol can be obtained per year from one hectare (1 odt of wood produces 150-200 liters of ethanol depending on the type of wood). This quantity of ethanol is lower than the one that can be obtained from 1 ha of sugarcane but forests (natural or managed) require land of lower quality and the availability of forests is very large in many countries of the Third World.

It is interesting to point out that the fundamental change when moving from sugarcane to celulose as a raw material for the production of alcohol, is to reduce the contribution of the agricultural raw material to the cost. Sugarcane represents approximately 80% of the final cost of alcohol. In the alcohol production from corn in the United States the percentage is about the same. Wood however represents only 40%, the other costs being due to larger expenditures in energy and other products in the industrial phase as shown in Table 6. One can therefore expect technological progress that will lower these expenditures in the case of wood.

place Table 6 near here

Table 7 lists the 15 countries of the Third World with the largest forested areas, representing more than 70% of the total. Assuming that only 5% are used and taking the average yield of 14 odt/ha/year these forests could supply on a renewable basis 160-210 billion liters of alcohol per year which correspond to 2.5 to 3.6 million barrels per day in a total consumption of approximately 6 million barrels per day in all the non-OPEC Third World countries. This is

TABLE 6

Percentual costs in the production of ethanol from different raw materials

	Sugarcane [a]	Wood [b]	Corn [c]
Raw material	79.8	37.7	72.5
Labour	0.7	0.6	4.0
Materials	0.8	23.9	1.5
Energy	0.7	20.4	8
Maintenance and others	2.9	2.5	5.5
Depreciation	15.1	14.9	8.5
Total	100.0	100.0	100.0

[a] Brazilian experience

[b] Produção de combustíveis líquidos a partir da madeira - Informações básicas - IBDF - Ministério da Agricultura, Brasil, 1979.

[c] Report of the Energy Research Advisory Group on GASOHOL - April 29, 1980 - Department of Energy, USA.

a considerable amount of liquid fuel although still minor compared to the approximately 60 million bpd consumed daily in the world.

place Table 7 near here

IV. CONFLICTS WITH SOCIAL AND ENVIRONMENTAL GOALS

Although rather successful in promoting gasoline substitution in Brazil, the alcohol program has already worsened existing social problems or produced new ones in the following areas:

a) production of other foodstuffs or subsistence crops.

b) changes in the pattern of land utilization and unemployment of the labour force.

c) enhancement of the concentration of wealth in the hands of a small fraction of the population.

From the environmental point of view two other problems have became rather acute:

d) the production of each liter of alcohol leads to approximately 15 liters of stillage which has been discharged in rivers and meadows without any serious consideration of degradation of the environment.

e) the use of vast areas of land in a monoculture such as sugar cane might have adverse ecological effects.

In what follows we will discuss these points.

a. Production of other foodstuff

Agricultural products in LDC's serve in general two main purposes: meeting hunger as foodstuff (in the form of blackbeans, corn or rice) and earning foreign exchange through exports. In the case of Brazil the growth of the alcohol program has been such that it is using 1 million ha

TABLE 7

Forested Areas

	Forests and woodlands x 10^3 ha	Land area x 10^3 ha	Fraction of Land area
Brazil	509,000	845,651	60
Indonesia	122,000	181,135	67
China	121,500	930,496	12
Zaire	120,900	226,760	53
Australia	107,000	761,793	14
Sudan	91,500	237,600	38
Colombia	77,190	103,870	75
Peru	73,800	128,000	58
Angola	72,680	124,670	59
Mexico	70,700	192,304	37
India	65,500	297,319	22
Argentina	60,220	273,669	22
Bolivia	56,200	108,547	52
Venezuela	47,970	88,205	54
Burma	45,274	63,888	70
Zambia	37,300	74,072	50
Total	1,678,734	5,288,328	743

Source: 1978 FAO Production Yearbook - Food and Agricultural Organization (FAO) of the UN. Rome, Italy, vol. 32 (1978).

of land at present; this area will grow to 3 million ha in 1985. The 2 million ha of good land which will be used could produce 500,000 tons of black beans, 1,500,000 tons of rice and 1,500,000 tons of corn which represent roughly 20%, 17% and 8% of the present production of such crops . The production of alcohol is therefore being made at the expense of these basic crops and one could ask why very much needed government loans go frequently into sugarcane production and not in more basic crops.

Another way to express the conflict between the production of fuel and foodstuff is to point out that the existing programs of expansion of agricultural production for liquid fuels, exports and food will require an expansion of the present area used at a rate of 7-8%/year while in the period 1968-1977 the rate of growth has been only 3,7%. There obviously will not be room for all of them, except by expanding the arable land area which is not possible in the more populous areas of the country.

b. Patterns of land utilization

The expansion of the sugarcane production has been taking place mainly on the fertile lands of the state of São Paulo where it has been displacing more traditional crops (coffee, soyabeans and cotton). The argument has been made that such crops are mainly oriented toward exports, i.e. the earning of foreign exchange to pay for essential imports, mainly petroleum; therefore it might make sense to grow sugarcane and produce alcohol which could reduce these petroleum imports. This is a rather controversial question in Brazil.

On the other hand however large sugarcane plantations are being established in regions where 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, maize, 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 when it is difficult to get jobs. They become therefore seasonal labourers for the large plantations, since sugarcane is a 6-month per year activity.

c. Concentration of income

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.

d. Pollution

The production of large quantities of stillage ("vinhoto") was initially a very serious problem because of the large quantities produced (almost 60 billion liters in 1980). Stillage is however very useful as fertilizers, but it has to be transported to the fields and therefore concentrated to some extent in order to decrease the amount to be transported.

Several schemes have been developed for this purpose using waste heat from the alcohol refineries. Another scheme is to produce biogas from the stillage through anaerobic digestion and use the final residue as a fertilizer. The production of proteins for cattle feeding is also technically possible.

These methods require new investments and the producers have been reluctant to make them until forced by regulations which forbid the dumping of stillage in rivers and meadows, a practice that was destroying completely the "habitat" of fish in many rivers in the State of São Paulo.

Present regulations are becoming quite strict and will probably lead to a solution of the problem.

e. Ecological effects of a monoculture

It is probably too early to notice the consequences of the adoption of an intensive system of land utilization as required by sugarcane except for the social consequences mentioned above. It is however rather impressive to have large areas completely covered by sugarcane plantations and undoubtedly many species of animals and plants have been eradicated from several of these areas since no heavens(such as small sanctuaries or trees) are left intact. The vulnerability of monocultures to diseases is becoming an increasingly worrysome factor for the future of the Program.

V. CONCLUSIONS

In the light of the above discussion it is possible to expect that in the next 10-20 years the production of alcohol for use as fuel could increase to approximately 4 million barrels per day in LDCs as a whole.

The main candidates for the use of sugarcane as a basic raw material are India, Brazil, Cuba, China, Mexico and Pakistan. The candidates for the use of wood from managed forests as a raw material are Brazil, Indonesia , China, Zaire, Australia and Colombia.

The use of celulosic materials will enter the market slowly but by 1990 it is expected to make a substantial contribution.

While the environmental constraints seem to be manageable, the use of sugarcane for alcohol production has had some adverse social consequences in Brazil. The use of wood as a raw material will attenuate the social adverse consequences since land used for reforestation does not compete with land used for food production.

The economical units for alcohol production are typically 100,000 liters per day requiring the use of 10.000 hectares of land; this is not a decentralized way of production. The use of mini (1,000 liters per day) and micro (100 liters per day) distilleries has not yet been proved to be economically competitive. In addition, most of the alcohol produced is trucked to large reservoirs and distributed to large urban centers by the usual methods of distributing gasoline (either pure or in the form of a 20% gasohol mixture).

The possible large producers of alcohol (from sugar cane or wood) are more evenly distributed in the southern hemisphere than the OPEC oil producing countries which are largely concentrated in the Persian Gulf.

It seems possible therefore to many Third World countries to develop their own base of production of liquid fuels and free themselves from oil imports, using biomass as a resource.

Such programs are not necessarily oriented to solve social problems and actually can worsen some of them. Just to give one example one could point out that in the State of São Paulo, Brazil, automobile owners (which are the main beneficiaries of the alcohol program) are a small minority; 22% of the families own 86% of the automobiles. One could therefore consider the alcohol program as a program favouring small elites and the car manufacturers (which are all foreign owned).

On the other hand, the alcohol program could generate jobs and enhance the self-reliance of developing countries, reducing imports and the need for foreign exchange.

BLOCK DIAGRAM OF AN ALCOHOL DISTILLERY

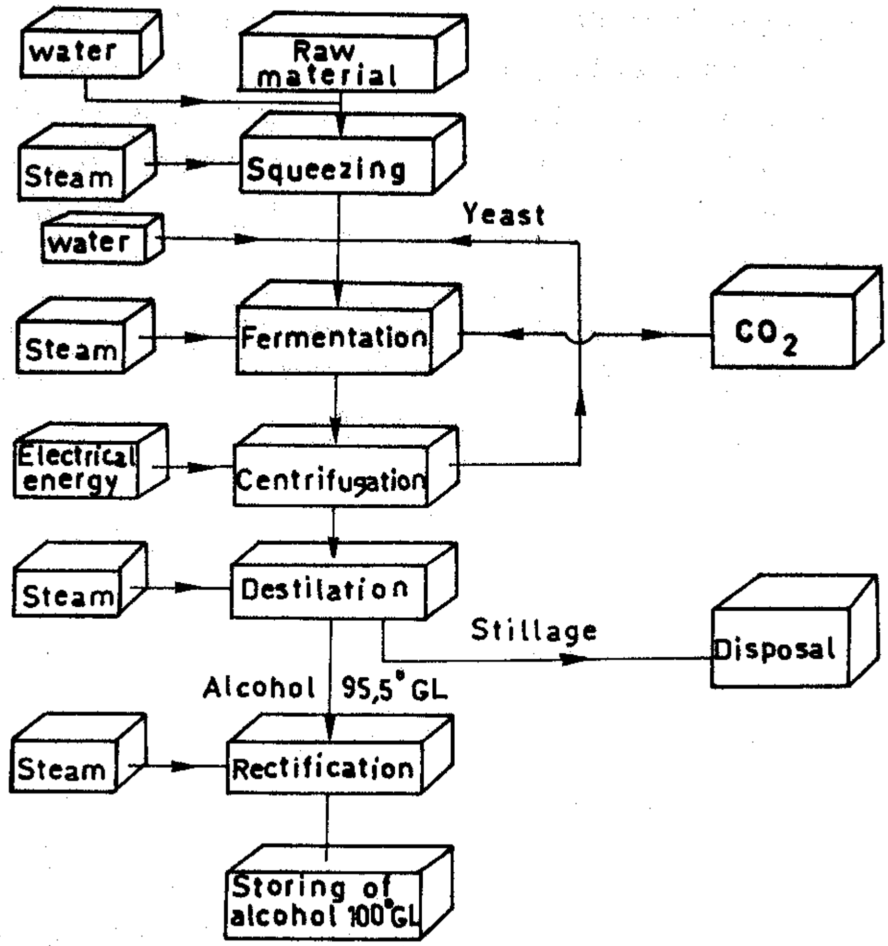

FIGURE 1