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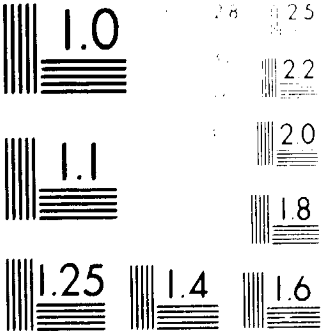
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FERMENTATION ETHANOL PRODUCTION

COST MODEL*

Prepared for the United Nations Industrial Development Organization

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF DRAWINGS

1.

EXECUTIVE SUMMARY

The sudden escalation in fossil fuels prices in 1973 impacted markedly on the economy of countries lacking self sufficiency in oil production. The effects were more acute mainly in developing countries with the worsening of problems in the balance of payments, inflation rates and slowdown in GNP growth rates.

Expectation of ever-increasing prices of fossil fuels and their long term physical exhaustion prospects prompted the search for alternative sources of energy, based on renewable feedstocks. Fermentation ethanol from agricultural feedstocks seems to be a feasible alternative for many countries, for short term lessening dependence on imported crude oil/distillates.

In this context, UNIDO - United Nations Industrial Development Organization retained CTP - Centro de Tecnologia Promon to develop a cost model of fermentation ethanol production. Such a model is expected to contribute to the analysis of the implementation of ethanol programs in developing countries.

This report covers the development of a financial cost model for fermentation ethanol production based on sugarcane molasses, sugarcane juice and mandioca (cassava) and for different rated capacities ranging from 5 to 240 m^3 of absolute ethanol per day.

The cost model developed herein explicitly measures inputs and outputs in financial terms. No attempt was made to incorporate social cost/benefit analysis due, mainly, to the difficulty of quantifying the opportunity costs of production factors for various countries.

The financial cost model was developed in general terms to allow assessment of the economics of ethanol production agroindustrial systems by specific developing countries reflecting their intrinsic technical and economic conditions.

The model includes agricultural costs, processing costs and byproducts credits for the specified range of capacities. The model was based on the current technologies for processing molasses, sugarcane juice and mandioca into ethanol in Brasil. The most reliable technical and economic data were gathered from Brasilian farmers, ethanol distillers and equipment manufacturers engaged in the Brasilian National Alcohol Program. All figures presented reflect the economic situation prevailing in Brasil by April, 1980 and were translated into US currency by an exchange rate of Cr$50,00/US$. The Brasilian case should serve only as a reference for the assessment of the economics of ethanol programs in other developing countries.

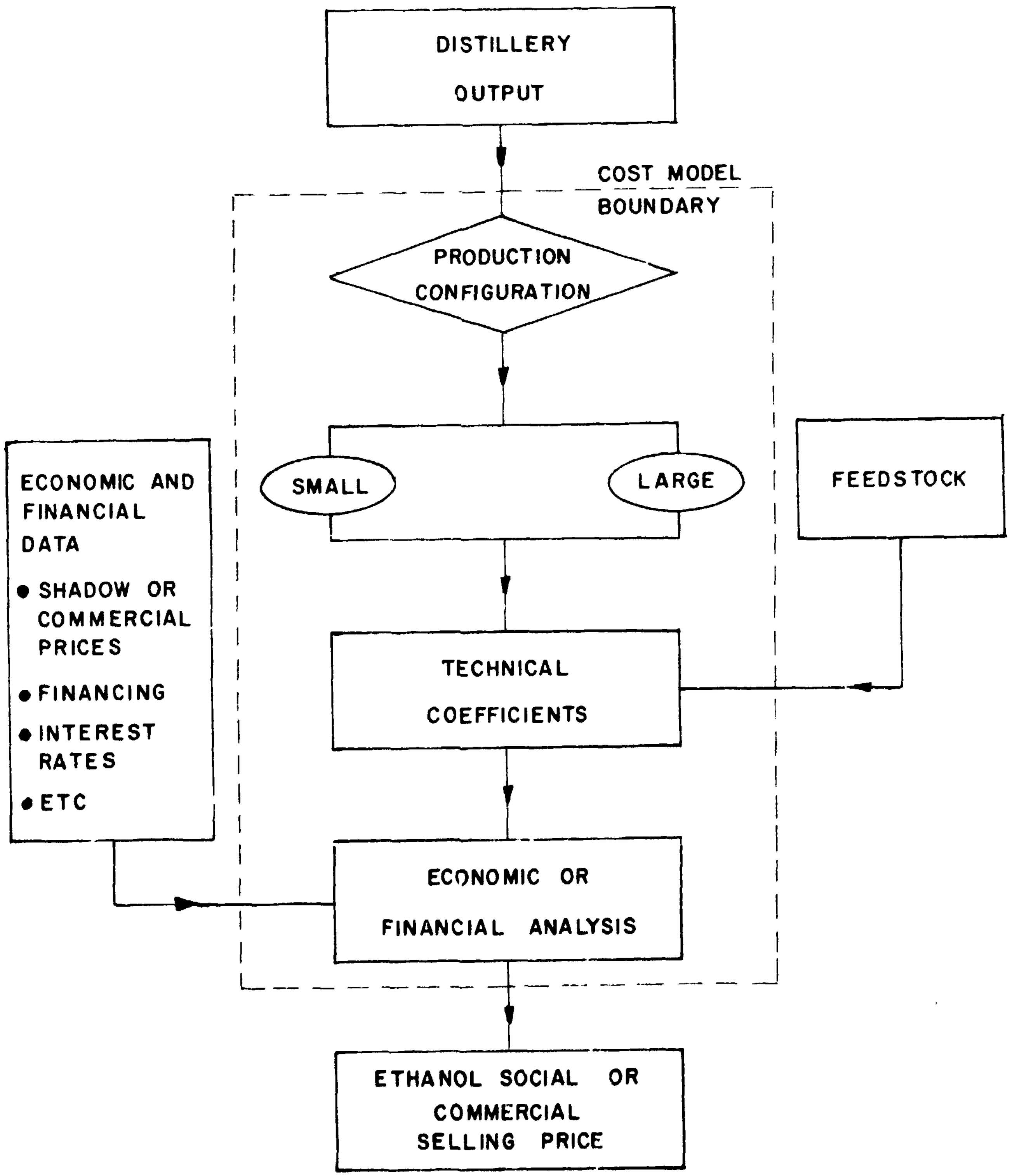
In the development of the financial cost model, CTP adopted the methodology presented in the Figure herein after. For each agricultural feedstock (molasses, cane juice and mandioca) and for each distillery concept (small or large scale), the investment in the agricultural and industrial sectors of the agrosystem are determined (see Chapter 5). Based on the material and energy balances, shown in Chapter 4, the operating costs are then estimated.

Adopting the DCF - discounted cash flow method, it is possible to calculate the selling price of ethanol (FOB distillery). For this calculation a set of economic conditions have to be fixed, e.g., the rate of return on investment. The model is able to measure the benefits of subsidized financing on the selling price practiced in an inflationated economy, besides technological sensitivity. Financial sensitivity analysis of ethanol price to rate of return on investment, financing conditions, process input price, inflation rate can be performed with the model.

A complete example for an independent distillery based on sugarcane juice with a daily rated capacity of 120m^3 of absolute ethanol is assessed using the cost model developed and adopting current Brasilian economic conditions. Financing, as stated in the Brasilian Alcohol Program, is considered in this ethanol price calculation. A resulting price of US$ 303/m^3 of ethanol, compared to the current retail price of gasoline - US$ 560/m^3 - shows that gasoline replacement by ethanol is economically advantageous besides the fact that ethanol is domestically produced, thus contributing to the intensification of the development of the whole country.

FINANCIAL COST MODEL

-BLOCK DIAGRAM-



2. INTRODUCTION

This study comprises the development of a financial cost model for assessing the economics of fermentation ethanol production from sugarcane molasses, sugarcane juice and mandioca. It covers a range of capacities from 5 to 240 m^3 of absolute ethanol per day.

Introducing this subject, a brief discussion on problems and opportunities associated to ethanol production envisioning conventional fuel replacement in developing countries is presented in Chapter 3.

Chapter 4 describes the state-of-the-art of fermentation ethanol production based on agricultural feedstocks. Different distillery concepts were assessed in order to identify the technological and agroeconomic aspects as well as the social and economic impacts resulting from the implementation of an agroindustrial system for ethanol production. Material and energy balances presented in this Chapter reflect the current technologies adopted by Brasilian distilleries in the agricultural and industrial components of the ethanol complex. These technologies have been used in Brasil for several decades with little improvement in the ethanol global yield (m^3/ha-yr).

Investments and operating costs for different capacities and feedstocks are detailed in Chapter 5. Figures are based on the Brasilian situation in April 1980.

The adopted methodology, the bases and the mathematical expressions upon which the cost model was built are thoroughly discussed in Chapter 6. A complete example based on a typical sugarcane independent distillery with a daily ethanol output of 120 m^3 was assessed to demonstrate model mechanics.

The development of Brasil's ProAlcohol, the attainment of its targets and the analysis of its consequences on regional and national bases are briefly presented in Appendix A. Established in 1975, the ethanol program envisioned mainly oil import reduction by substitution of oil derivatives. Associated to then prevailing low sugar prices, social and economic factors prompted the creation of the program.

Since ethanol price is administered by the Government as a function of its end use, a special topic covers the incentives and bases for the establishment of these prices.

3. PROBLEMS AND OPPORTUNITIES OF FERMENTATION ETHANOL PRODUCTION IN DEVELOPING COUNTRIES

Since 1973, with the deflagration of the world energy crisis associated to its economic, political, social and strategical implications, energy planning and policy-making have increasingly become a critical component of national development planning activities. This becomes more relevant in relation to developing countries since their decision-making is handicapped particularly when dealing with new and controversial issues such as alternative sources of energy. The major reasons accounting for this are:

. Scarcity of financial resources;

. Increasing difficulties in obtaining foreign financing;

. Reduced domestic technology, know-how and research capabilities;

. Reduced management, planning and policy-making capabilities;

. Limited access to information and reduced capability of identifying and understanding problems and opportunities associated with energy production.

Consequently, fermentation ethanol production programs in developing countries may be seriously jeopardized unless special efforts are made towards better planning and implementation to overcome the obstacles that are likely to emerge. Such a strategy should provide the decision-making process with means to assess the problems and opportunities of fermentation ethanol production. Such a posture should result in consistent information upon which to:

. Improve management of financial, human, natural and technological resources;

. Maximize the social benefit/cost ratio;

. Facilitate decision-making processes;

. Facilitate technology research and development activities;

. Optimize allocations and utilization of resources;

. Better qualify for international financial assistance;

. Identify potential barriers of psychological, political and social nature;

. Guarantee penetration of ethanol into the local energy commodity market.

With the aim to provide UNIDO with a broader perspective of the problems and opportunities associated with the implementation of fermentation ethanol production programs in developing countries, CTP has prepared a simplified conceptual planning and policy-making strategy. It illustrates generic guidelines for coordination of decision-making efforts of developing countries in order to achieve a successful implementation of such mechanisms in ethanol programs.

CTP's proposed planning and policy-making strategy is multipath, iterative and dynamic in nature. The different activities required for planning and policy-making, in a logical sequence of phases, should contribute to:

- Avoid deleterious interference of ethanol program objectives on other simultaneous development programs;
- Enable successful achievement of ethanol program objectives;
- Avoid adoption of conflicting objectives;
- Permit the grouping of activities by categories enabling information to be processed through specific and coherent criteria;
- Maximize use of internal capabilities (synergism);
- Avoid conflicts in the global analysis due to selective elimination of the non-pertinent criteria of each phase;
- Enable the generation of overall and sectoral policies as well as the final elaboration of a global integrated policy.

Figure 1 presents the dynamics of the planning and policy-making mechanisms. This figure suggests an iterative process where the actual consequences arising from program implementation should be continuously recycled to adjust global and specific objectives and consequently alter global and sectoral policies.

The various phases required in planning the implementation of energy programs are summarized in Table 1. The matrix presented exemplifies a set of mechanisms to be adopted in the elaboration of an alcohol program policy.

The first step corresponds to the assessment of the economic backgrounds of the country. It includes the establishment of investment alternatives for the specific situation and utilization of available resources and their trade-off analysis. This refers particularly to the externalities and internalities produced in the economy as a whole. A general and current picture evidences the competition between energy, capital goods and food production programs mainly in developing countries.

FIGURE I

DYNAMICS OF PLANNING AND POLICY-MAKING MECHANISMS FOR A FERMENTATION ETHANOL PRODUCTION PROGRAM

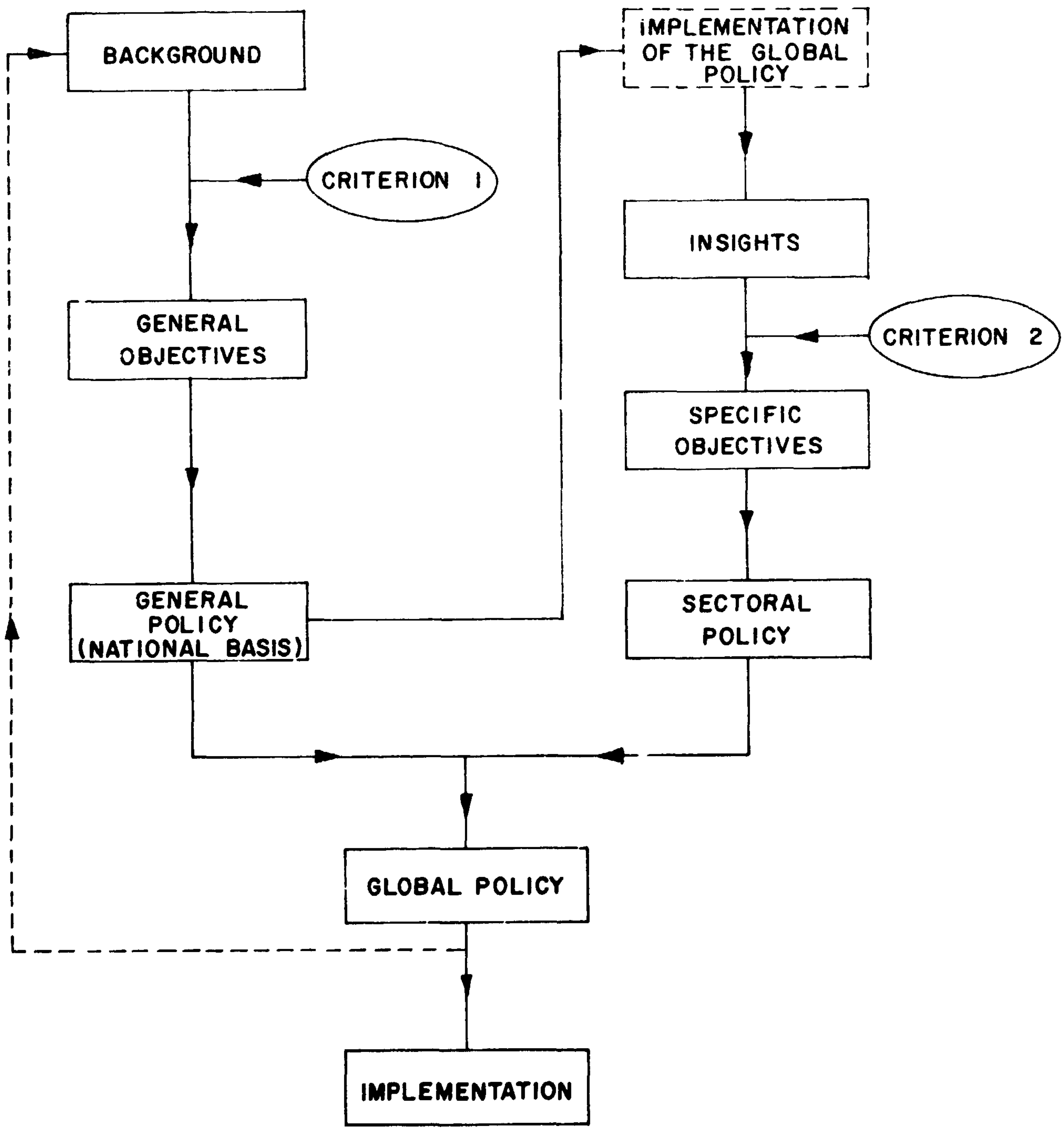


TABLE 1

MATRIX OF THE PLANNING AND POLICY-MAKING MECHANISMS FOR THE IMPLEMENTATION OF A FERMENTATION ETHANOL PRODUCTION PROGRAM

BACKGROUNDS		GENERAL OBJECTIVES		INSIGHTS			SPECIFIC OBJECTIVES		GLOBAL POLICY	
ESTABLISHMENT OF A SET OF INVESTMENT ALTERNATIVES AND THEIR TRADE-OFF ANALYSIS	▷	QUANTITATIVE ESTIMATE ACCORDING TO NATIONAL NECESSITIES	▽	IDENTIFICATION OF CAPABILITIES AND CONSTRAINTS	DEFINITION OF THE POTENTIAL OUTPUTS	◁	QUALITATIVE SELECTION AND HIERARCHIZATION	▽	DEFINITION OF SPECIFIC SUB-PROGRAMS	ELABORATION OF SPECIFIC POLICIES FOR DIFFERENT TIME-FRAMES
• PRODUCTION OF ALTERNATIVE ENERGY SOURCES OTHER THAN ETHANOL • ALTERNATIVE ALLOCATION OF INVESTMENT WITH HIGHER TRADE-OFF VALUE: — PRODUCTION OF CAPITAL GOODS — PRODUCTION OF RAW MATERIAL — PRODUCTION OF FOOD • EXTERNALITIES • INTERNALITIES • OTHERS	CRITERION 1	• PRODUCTION OF FERMENTATION ETHANOL (m^3/YEAR) • DISPLACEMENT OF X% OF GASOLINE NATIONAL CONSUMPTION • SUBSTITUTION OF OTHER PETROLEUM DERIVATIVES • REDUCTION OF ENERGY IMPORT BILL • TIME-FRAME DEFINITION (SHORT, MEDIUM AND/OR LONG TERM) • OTHER	GENERAL POLICY (NATIONAL BASIS)	• IDENTIFICATION OF POTENTIAL FEEDSTOCKS • IDENTIFICATION OF AVAILABLE TECHNOLOGIES • GEOGRAPHIC SUITABILITY • TECHNICAL FEASIBILITY • FINANCIAL ANALYSIS • SOCIO-ECONOMIC ANALYSIS • ENVIRONMENTAL AND ECOLOGICAL ANALYSIS • AGRICULTURAL TECHNOLOGICAL • OTHERS	• IMPACT ON THE NATIONAL ENERGY MATRIX • IMPACT ON BALANCES OF COMMERCE AND PAYMENTS • IMPACT ON EMPLOYMENT • SOCIO-ECONOMIC IMPACT OF THE DIFFERENT ENERGY ROUTES AND TECHNOLOGIES • IMPACT ON RURAL DEVELOPMENT STANDARDS • IMPACT ON TECHNOLOGICAL AND INDUSTRIAL DEVELOPMENT • OTHERS	CRITERION 2	• SAVING OF ASSETS • PROMOTION OF RURAL DEVELOPMENT • PROMOTION OF TECHNOLOGICAL AND INDUSTRIAL DEVELOPMENT • GENERATION OF EMPLOYMENT • MINIMIZATION OF PETROLEUM IMPORTS • MINIMIZATION OF FOREIGN CURRENCY EXPENDITURES • OTHERS	SECTORAL POLICY	• SMALL SCALE FERMENTATION ETHANOL PRODUCTION SYSTEMS: — UNICELULAR — ASSOCIATED — COOPERATIVE BASED ON: — SUGARCANE — MOLASSES — MANDIOCA — OTHERS • LARGE SCALE FERMENTATION ETHANOL PRODUCTION SYSTEMS, BASED ON: — SUGARCANE — MOLASSES — MANDIOCA — OTHERS • END-USE TEST AND DEMONSTRATION PROGRAMS	• FINANCING PROGRAMS • TECHNOLOGY DEVELOPMENT AND TRANSFERENCE PROGRAMS • INSTITUTIONAL SUPPORT POLICIES • FISCAL INCENTIVES • OTHERS

Through a set of pertinent criteria (e.g., minimization of foreign currency expenditures) these programs can be hierarchized. In a national basis, it will be necessary to establish quantitative objectives as, for instance, the amount of oil derivatives to be displaced by alternative fuels in a defined time-frame.

A clear example can be found for a traditional molasses exporting country intending to implement a fuel alcohol program in order to save foreign currency. It could be possible that the revenue obtained from molasses sales could pay the oil import bill and yield a net positive balance, in the short term.

The necessity of establishing general guidelines is characterized through a general policy. It should include financing policies, definition of institutional participation and support, research and development and others. The implementation of an ethanol program based on this general policy (or the simulation of this implementation) will provide enough information about the effects of the actual accomplishment of the general objectives.

The scope of the present study, i.e., the elaboration of a cost model, supplies the bases for financial analysis and, eventually, the socio-economic analysis of an ethanol program. As seen in Table 1, these are a small part of the analytical phase of developing programs. In the specific case of ethanol programs, these evaluations are critical since competitiveness with oil derivatives should be achieved.

The final result to be obtained is a global policy entailing two main action lines:

(1) Definition of specific sub-programs such as definition of scale concepts, potential feedstocks, geographical production regions and end-use test programs;

(2) Elaboration of specific policies such as financing programs, technology transfer, research and development programs, institutional support and fiscal incentives.

As a consequence, there results the estimated cost of the total program. Thus, for developing countries, the successful implementation of an ethanol program will depend heavily on meeting pre-established policies and goals, financial and physical implementation schedules.

4. STATE-OF-THE-ART OF FERMENTATION ETHANOL PRODUCTION

Fermentation ethanol is the result of the metabolic conversion of sugars by yeasts. This process has been known since immemorial days and was used in the production of all kinds of drinking alcohol - beer, wine, spirits - thus providing energy to humans.

More recently ethanol has been employed commercially as a fuel, in addition to other industrial uses as a solvent, chemical feedstocks and in beverages. Fuel ethanol has been employed mainly in automotive systems, pure or blended with gasoline.

Fermentation ethanol is the main product of an agroindustrial activity. Consequently, its cost and availability are related to factors affecting agricultural activities.

4.1 Agricultural Feedstocks

A variety of sugar containing substrates are employed in the production of fermentation ethanol. Some substrates already contain fermentable sugar. Others contain starch or cellulose which are first converted into fermentable sugars. Commercially important substrates for fermentation ethanol are presented in Figure 2.

The major process steps required in fermentation ethanol production are shown in Figure 2 as well as byproducts cogenerated.

This Chapter is dedicated to the description of the agricultural and industrial activities profile of ethanol production from sugarcane and mandioca. The technical parameters presented along this Chapter reflect the current Brasilian situation.

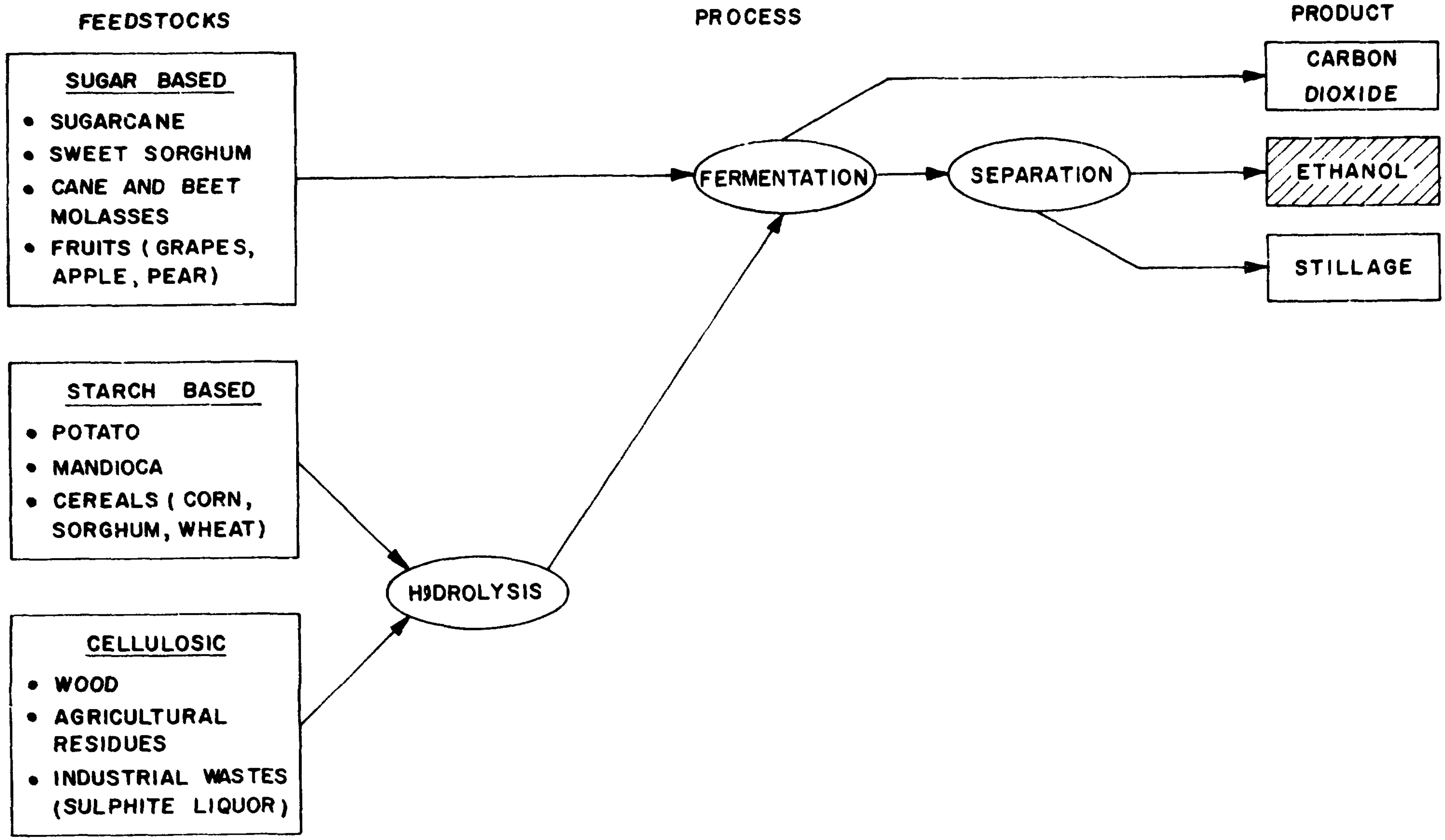
An agroindustrial system for ethanol production comprises two distinct phases, although tightly interelated: agricultural feedstock production and industrial conversion. It has been verified that agricultural activities constitute the bottleneck of the whole process while industrial conversion has been presenting a satisfactory performance though not optimized for fuel alcohol production.

4.1.1 Sugarcane

Sugarcane, a traditional raw material responsible in Brasil for almost all ethanol production, presents many advantages as an agricultural feedstock for fermentation ethanol production:

FIGURE - 2

FERMENTATION ETHANOL PRODUCTION SCENARIO



. Extensive cultivation experience in many countries in the world. Most countries which actually cultivate sugarcane already have reasonable infrastructures for alcohol production.

The productivity figures show variations from country to country as shown in Table 2. These variations are due not only to climatic, soil and environmental conditions, but also, and to a very large extent to cane cultivation practices.

. Accumulated experience in ethanol production with a well established technology.

. Sugarcane alcohol can be 100% (percent) energy self-sufficient due to the availability of bagasse. Excess bagasse from an independent distillery can be converted into electricity, among other possible alternatives.

On the other hand there are some disadvantages in utilizing sugarcane as a feedstock in ethanol production. These are:

. Sugarcane is a very demanding crop in terms of the edaphoclimatic requirements (e.g. rainfall between 1000 mm and 2000 mm a year and a minimum temperature of $18^{o}C$) (ref. 1). This might set very restrictive limits for its production. Consequently in Brasil there will be limitations in sugarcane production increase to cope with sugar production requirements and fuel alcohol production demands.

. Consequently there is a strong geographical concentration of sugar and ethanol production. Such a concentration can be seen in the Brasilian case where almost all cane cultivation is done in the Southeast and along a narrow coastal fringe in the Northeast. Evidently this concentration results in important economic, political and social implications (see item 4.2.2).

TABLE 2

Sugarcane: World agricultural productivities

Country	(t/ha)	(t/ha/yr) 1)
Australia	84	78
Bangladesh	35	35
Brasil	56	50
China	85	85
Fiji	48	45
Hawaii	241	120
India	56	56
Indonesia	85	65
Philippines	53	53
Taiwan	76	76

Note: Figures were adjusted to the annual cycle when the 1st. cutting takes more than 12 months.

Ref.: (2)

. In the medium term, the increase in ethanol demand will promote *geographical expansion* of cane cultivation into areas with less attractive edaphoclimatic and soil conditions. Consequently there will be an increasing demand for fertilizers and irrigation programs, which will tend to increase the cost of sugarcane, and decrease the net energy ratio of sugarcane alcohol production.

. Historically alcohol has been a byproduct of sugar production and, therefore, ethanol production will be highly dependent and vulnerable to fluctuations of sugar prices in the international markets if molasses based distilleries predominate.

. Due to the large demands for sugarcane products (sugar, alcohol and molasses) cane production is not economically feasible on small scale.

. Therefore expansion of sugarcane cultivation could compete with production of foodcrops.

. Since sugarcane harvest takes approximately 6 months/year, the distillery is idle half the year.

Given the vulnerability of sugarcane to disease and climatic adversities, it would be unwise to base the entire alcohol production on a single feedstock. (ref. 3).

4.1.2
Molasses

Molasses is the byproduct of raw sugar manufacture. The heavy, viscous liquid separated from the final low-grade syrup from which no further sugar can be crystallized by the usual methods is known as blackstrap molasses. It is generally described as such because it is not used directly for human consumption.

The main components of molasses are reducing sugars which account for more than 50% w/w. Molasses contained sugars justify use of molasses as a feed ingredient and as a substrate for fermentation products (ethanol, citric acid, monosodium glutamate).

World fermentation ethanol production amounted to 9 million cubic meters, in 1975. Molasses alone was responsible for 34% of this total, the bulk of it being contributed by sugarcane molasses. The beverage market absorbs almost all molasses alcohol production.

Therefore, the high costs of ethanol production from molasses are supported by the high selling price of beverages. However for fuel alcohol purposes process economics have to be improved.

In Brasil and other traditional sugar producing countries, ethanol can be produced from molasses at a low cost at distilleries adjacent to sugar mills. The already existing installations (boiler, electricity generators, cooling tower, etc.) in addition to lower feedstock transportation costs result in lower operating and capital costs of ethanol production.

The inherent advantages of sugarcane as a feedstock, as described previously, are also applicable to cane molasses. The implementation of a fuel ethanol program based on imported molasses is therefore hardly justified.

4.1.3
Mandioca (Cassava)

The utilization of mandioca as a feedstock for the fermentation ethanol production has been increasingly considered in the world. Starch contained in roots of mandioca can be converted to fermentable sugars from which ethanol is obtained.

The aerial part of the plant (leaves, branches, stem) can be used to generate part of the energy required for the industrial processing (ref. 4). Mandioca is considered as a potential feedstock for ethanol production because of the following reasons:

Mandioca cultivation does not require special edaphoclimatic conditions, although the yields are sensitive to qualitative variations in those conditions. Consequently it is possible to utilize areas with relatively poor land. There would then be little dislocation of other agricultural activity particularly food crops. At the same time, it enables poor and/or remote sections of the country to produce their own energy (ethanol).

Mandioca's high concentration of carbohydrates, makes it a very promising alcohol feedstock. This tendency will be accentuated as mandioca agricultural productivity increases from the current recorded world average of 9.5 (t/ha) (see Table 3).

TABLE 3

Mandioca: World Agricultural Productivity

Country	(t/ha)
Brasil	14.7
Ghana	11.3
India	16.7
Indonesia	7.4
Mozambique	4.8
Nigeria	9.9
Thailand	16.3
Tanzania	7.5
Uganda	4.0
Zaïre	12.9

Ref.: (5)

. Mandioca harvest can be carried out throughout the whole year. This enables the continuous operation of the distillery. The different climatic conditions do not affect the development nor the harvesting of mandioca, except for minor fluctuations in the starch content.

. As opposed to sugarcane mandioca fermentation alcohol would not compete directly with large scale export activities; therefore, it would be less vulnerable to international price movements. However depending on specific cases, it might be better to export mandioca pellets rather than to produce ethanol from mandioca.

- In spite of the limited commercial experience in mandioca alcohol production compared to sugarcane alcohol, it has shown to be adequate to certain markets (see item 4.2.3).

- Mandioca cultivation for ethanol production, might help to increase rural employment. Mandioca cultivation is labor intensive and can be carried out throughout the year.

- If mandioca feedstock for the distillery operation is predominantly supplied by small farms, it is then feasible to implement mandioca pellets and/or chips supply system as opposed to fresh roots supply system. Marked reduction of feedstock transportation costs can then be accomplished.

- Drawbacks of mandioca cultivation for conversion to alcohol are: worldwide there is relatively small experience in large scale mandioca cultivation. Hence there are risks in setting up large agroindustrial system for ethanol production. Of particular importance are adequacy and effectiveness of mandioca cultivars and disease control methods.

- Probably developing countries will require imported process inputs such as enzymes for the industrial processing of mandioca.

- Since mandioca does not yield its own bagasse complementary energy sources will be required. This situation might change in the short/medium term through genetically improved cultivars that maximize aerial/root mass ratio. Also the conversion of stillage into methane rich fuel gas via fermentation is another short term alternative to improve the energy balance of the process.

4.1.4 Sweet Sorghum

Sweet sorghum belongs to the same grass family as sugarcane. A juice, rich in sugar can be extracted from its stalk. At the same time, its grains have high starch conterts, which can also be converted to ethanol.

Edaphoclimatic requirements of sweet sorghum are less stringent than sugarcane. It has a short cultural cycle (3-4 months). Consequently sweet sorghum is a potentially promising feedstock for fermentation ethanol production.

The major advantages of sweet sorghum relative to ethanol production are the following:

- Same sugarcane ethanol distillery equipment can be used between sugarcane harvests. Coproduction of sugarcane and sweet sorghum seems therefore interesting. In such a case sweet sorghum can be used to feed the distilleries during sugarcane off-season.

- Whole plant utilization in ethanol production (stalks and grains).

- Sweet sorghum can grow in areas where precipitation reaches only 300 mm anually, which is very much less than the ideal requirements of sugarcane. Therefore it could be grown in regions where sugarcane would present lower productivity.

- Short growing cycle (4 months) allows sweet sorghum to be harvested 2-3 times a year (ref. 6).

- Processing similarity between sweet sorghum and sugarcane makes it easier to introduce sweet sorghum alcohol into the market.

- Sweet sorghum grains, which are rich in starch, can be used in animal feed or as supplementary source for ethanol production.

- Fibers left over after the extraction of the juices from sorghum stalks, can supply all the energy required for ethanol production.

Among the obstacles to the effective introduction of sorghum as a commercial feedstock for fermentation ethanol, are:

- Lack of commercial scale knowledge of production methods. The development of technologies for the stages of extraction of the sugary juices and for sorghum grain conversion to alcohol are necessary.

- There is no commercial scale experience of sorghum cultivation in Brasil. All the existing experience is based on very small scale experimental cultivation.

- Since it can yield sugar, sorghum will also be susceptible to the variations in international sugar prices but to a lesser degree than sugarcane.

4.1.5 Wood

Wood, or cellulosic residues via hydrolisis and fermentation can be converted into ethanol. Besides ethanol, the process yields a carbonaceous residue that can be made into an excellent metallurgical coke.

The advantages of producing ethanol from wood are the following:

. It generates as a co-product a high density metallurgical coke.

. Cellulosic feedstocks are as diversified as wood chips, forest industries wastes and agricultural crop residues.

. Conversion of wood and cellulosic residues into ethanol and coke results in a much higher carbon conversion efficiency than the conventional production of charcoal.

. In Brasil there is reasonable eucalyptus reforestation experience.

. Natural or reforested forests are more resistant to diseases and climate changes than agricultural crops grown for conversion to fuel.

. In contrast with the ethanol feedstocks, (sugarcane, mandioca), which compete in the food market, wood for fuel production competes in the fiber market.

. Eucalyptus is not demanding in edaphoclimatic conditions, and can be planted in various extensions of Brasil, at present unexploited. This could contribute to lessening regional disparities in social and economic development.

. There is experience in Brasil at a pilot scale, of ethanol production from wood, via acid hydrolisis.

On the other hand, wood and cellulosic residues present some disadvantages, such as:

. Lower global productivity (m^3 of ethanol/ha/yr) when compared to sugarcane and mandioca, for example. Enzymatic hydrolisis of cellulose, which would allow significantly higher productivities, is still incipient (refers 7; 8), making it difficult to estimate when it will be commercially available.

. Absence of commercial experience with acid hydrolysis in Brasil and of commercial enzymatic hydrolysis in the world.

. Larger area committment due to the vegetative cycle of eucalyptus of some 7 years.

. Lack of production capacity in Brasil for special steels required for acid hydrolisis process.

. Current process technology is net importer of energy.

4.1.6
Other feedstocks

. Agricultural residues

Agricultural residues refer to all residues resulting from harvest or processing of agricultural products, including (refs. 9; 10).:

. Crop residues, left behind in the field after harvesting;

. Residues from the processing of foodstuffs/rations, including unutilized fragments of the feedstocks;

. Wood residues, including branches, leaves and shavings resulting from cutting and processing of wood.

All these residues consist basically of cellulosic materials (cellulose, hemi-cellulose and lignin). Nevertheless in many cases, considerable quantities of starch and other carbohydrates, oils, greases, etc. are present. Residues are also heterogenous in their physical characteristics.

Main advantages of agricultural residues as feedstocks to production of ethanol are:

. Increase of agricultural productivity, attributing a commercial value to residues;

. Supply of additional energy sources in the rural areas;

. Environmental benefits in some cases.

Main barriers to the implementation of agricultural residues as ethanol feedstocks are:

. Lack of commercial technology to convert agricultural residues into ethanol;

. Dispersion and high water content of residues, resulting in costly collection and transportation.

. Removal of residues left in the soil after harvest contributes to errosion and water evaporation (ref. 9).

. Maintenance of carbon rate and soil structure is affected;

. Nutrient recycle is jeopardized.

. Babassu (Orbignya Speciosa)

Babassu, a native plant from North-Northeast Brasil, belongs to the palmaceas family. Babassu fruit is composed of three layers: external (epicarp); intermediary (mesocarp), and internal layer (endocarp).

Babassu appears to be an excellent alternative for energy production. Its epicarp is fibrous and can be used as primary fuel. The mesocarp is amilaceous and can be converted into ethanol. The endocarp is woody and can be used for the production of high quality, low ash, low sulfur coke. Finally the endocarp contains 4-8 nuts from which high quality vegetable oil is extracted. The oil could be used as fuel in Diesel engines.

Babassu presents some advantages as a feedstock for the production of ethanol such as:

- Babassu is a native plant in Brasil but in principle it could be introduced in tropical environments. Babassu does not require stringent edaphoclimatic conditions;
- As a native culture it does not require fertilizers and other inputs;
- Babassu's endocarp yields high quality coke.
- Babassu's fibers could supply the energy required in the processing of babassu;
- Babassu does not require replanting, since the fruit is the feedstock to be converted in ethanol, coke and oil;
- Babassu is well adapted ecologically and presents high resistance to plagues and diseases.

The disadvantages of utilizing babassu for the production of fermentation ethanol are:

- Natural dispersion of native babassu makes it costly to transport babassu fruits to processing unit. Domesticated babassu in new plantations in Brasil and in other countries could substantially reduce this problem.
- Optimal economics of babassu based ethanol production require integral use of the fruit.
- Babassu mesocarp has a lower starch content (125% aprox.) than other amilaceous sources;
- Babassu processing requires some imported inputs and equipment;

. Native babassu has low agricultural productivity (ton of fruit/ha/yr) and consequently low global productivity (m^3 ethanol/ha/yr).

. Sweet Potato

Sweet potato presents basically the same advantages as mandioca for the production of fermentation ethanol. However, some disadvantages are specific to potato as a feedstock for ethanol production.

. Smaller global productivity than mandioca (m^3 ethanol/ha/yr).

. Food market option is more important to potato than mandioca.

. Agricultural experience in Brasil on large scale is smaller than mandioca.

. Potatoes are more susceptible to adverse conditions of climate and soil.

4.1.7
Ethanol production potential from alternative feedstocks

In addition to the foregoing analysis on alternative ethanol feedstocks it is important to compare their potential ethanol productivities.

Table 4 shows the following productivities yardsticks for sugarcane, cane molasses, mandioca, sweet sorghum, babassu and wood: agricultural productivities (t/ha/yr), industrial yields (m^3/t), global yields (m^3/ha/yr) and co-products generated in each process (t/ha/yr). According to table 4, sugarcane has the highest global yield (3,6 m^3/ha/yr), followed by sweet sorghum (2,8 m^3/ha/yr) and mandioca (2,0 m^3/ha/yr) with current technologies.

TABLE 4
ETHANOL PRODUCTION POTENTIAL FROM VARIOUS FEEDSTOCKS

Feedstocks	Agricultural Productivity (t/ha/yr)	Industrial Yield (10^{-3} m^3/t)	Global Yield ($m^3/ha/yr$)	Important Co-products (t/ha/yr)
Sugarcane	53	67	3,6	Bagasse: 4,0
Cane molasses (a)	2	300	0,6	Sugar: 5,0
Mandioca	13	150	2,0	-
Sorghum				
. stem	35	60	2,8	-
. grain	2	360		
Babassu	2,5-10	80	0,2 - 0,8	Coke: 0,4 Oil: 0,1
Wood (b)				
. acid hydrolysis	20	85	1,7	Coke: 3,0
. enzymatic hydrolysis	-	150	2,4	

Notes: (a) Cane molasses with 55% of reducing sugars.

(b) Eucalyptus (50% humidity)

Refs.: (11; 12; 13; 14)

Key to fermentation ethanol production is energy self-sufficiency of the specific process route as long as the overall objective of the system is energy production. Table 5 shows aproximate figures for various feedstocks in terms of their respective self-sufficiency hectare. This concept measures the fraction of the cultivated area committed to ethanol production that is planted with the feedstock, the remainder being dedicated to other biomass process energy input (i.e. wood). According to Table 5 the feedstocks which present the highest energy self-sufficiency index are sugarcane (and molasses) and sweet sorghum provided bagasse/stalks are used for steam generation.

TABLE 5

SELF-SUFFICIENCY HECTARE

Feedstocks	Self-Sufficient hectare (%)
Sugarcane	100
Molasses	100
Mandioca	90
Sorghum	100
Wood (a)	90
Wood (b)	N.A.
Babassu	N.A.
Sweet potato	N.A.

Notes: (a) acid hydrolysis
(b) enzymatic hydrolysis

N.A. not available

Ref.: (12)

4.2
Agroeconomic Aspects

Small scale and large scale agroindustrial systems have different agroeconomic requirements, limitations and potentialities. Each size imposes different operating and administrative strategies, feedstock supply systems and related cost structures. Hence, it is important to revise major critical aspects of various agroindustrial systems of practical importance.

4.2.1
Small Scale Systems

Small scale agroenergy production systems are flexible enterprises. They supply limited amounts of feedstocks to normal distillery operation. Table 6 shows approximate figures for plantation land requirements and for production levels of raw materials needed to support various small scale distilleries.

TABLE 6

SMALL SCALE AGROENERGY SYSTEMS LAND[a]

AND PRODUCTION REQUIREMENTS

Crop		Capacities (m^3/day)		
		1	5	30
Cane Juice	Quantity (t/yr)	2,700	13,500	81,000
	Land (ha/yr)	50	250	1,500
	Alcohol production (m^3/yr)[b]	180	900	5,400
Cane Molasses	Quantity (t/yr)	600	3,000	18,000
	Land (ha/yr)	300	1,500	9,000
	Alcohol production (m^3/yr)[b]	180	900	5,400
Mandioca	Quantity (t/yr)	2,200	11,000	66,000
	Land (ha/yr)	170	850	5,080
	Alcohol production (m^3/yr)[c]	330	1,650	9,900

Notes:

(a) Only area harvested in a given year.

(b) Cane alcohol system operational cycle of 180 days/year.

(c) Mandioca alcohol system operational cycle of 330 days/year.

It is important to note in Table 6 that cane juice and molasses distilleries have an operational cycle of 180 days a year, while the utilization of mandioca enables 330 days a year of operation (Ref. 15).

Given specific rural scenarios, the implementation of small scale distilleries may be based on a variety of concepts. The major differences between such concepts are their administrative and organizational schemes and their structural characteristics. Figure 3 shows the layout of a single feedstock supplier system and its structure or configuration. A single feedstock supplier system is characterized by either an unicelular or an associated format. The former consists of an in-farm-distillery. Its organizational aspects are quite simple and concentrated. The farms within this size range will require external inputs of capital, technology and general production and maintenance inputs. Their labor profile, however, should consist mostly of family labor with exception of specialized technical assistance required for the implementation, running and service.

The associated format corresponds to a scenario in which a single feedstock producer is associated to a small scale distillery. In this case two operations may not share management or even be territorially contiguous.

In terms of the structural characteristics it is very similar to the previous model exposed. Split management and transportation of feedstocks over longer distances may increase unit production cost.

Another conception of small scale agroenergy production system is the cooperative feedstock supply system. Figure 4 shows the layout of such a cooperative. This concept puts together sufficient land, capital and working capacity, to enable implementation of larger distillery sizes (see Table 6). The setting of rural cooperatives originally geared for energy production could serve as a solid base for a broader rural integration. It could generate interesting economies of scale enabling cooperative groups to improve their financial equipment and technological resources availability(Ref.15). There is a need for government agriculture and development planning departments, regional development banks, international development and finance corporations and others to participate in the implementation of this kind of agroenergy system by means of loans, partnership, assistance, etc.

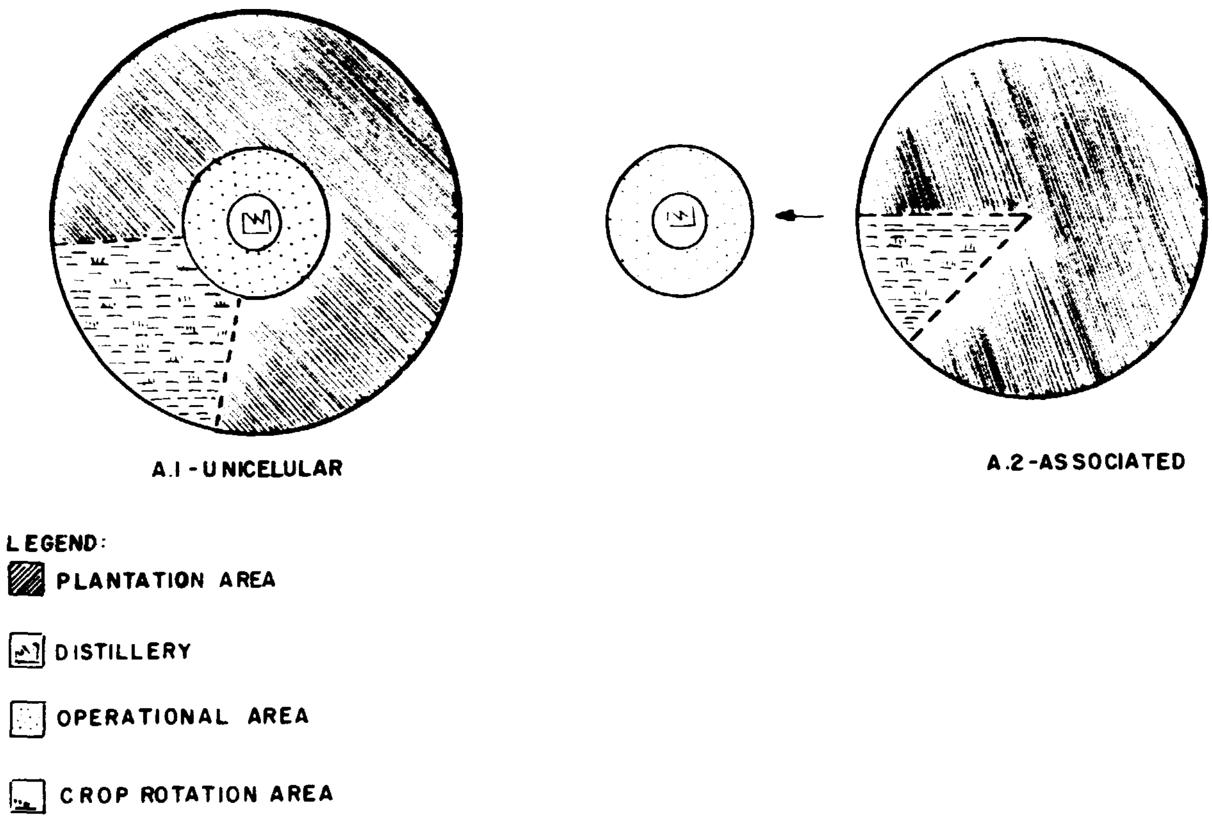
The structure of this cooperative system is still based on a small scale philosophy (see Figure 4). However, there is a greater complexity in its whole organizational and managerial aspects. The labor force still corresponds to family labor now operating at a large scale. The land is owned by each associate who runs his own feedstock production, supported and assisted by the cooperative. At a general level it can be expected that the external capital inputs will be required mostly for the distillery equipment and machinery.

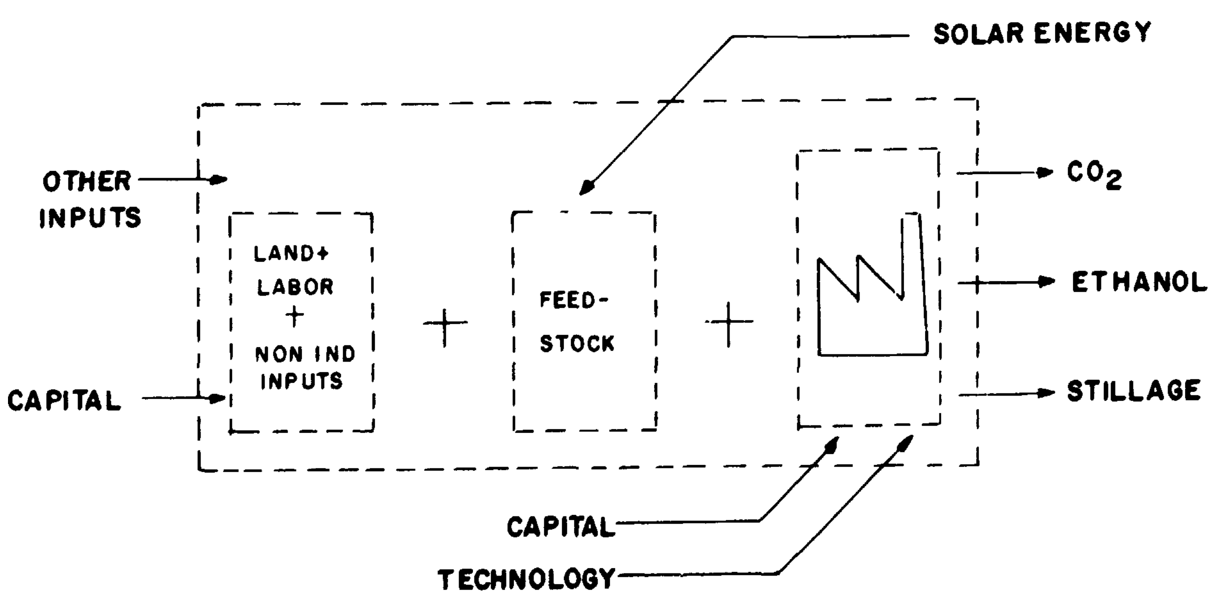
Management of the overall activities may be undertaken by external institutions or by the associated farmers. A relatively equidistant location between each feedstock producer and the distillery is recommendable.

FIGURE 3

SINGLE FEEDSTOCK SUPPLIER

LAY-OUT

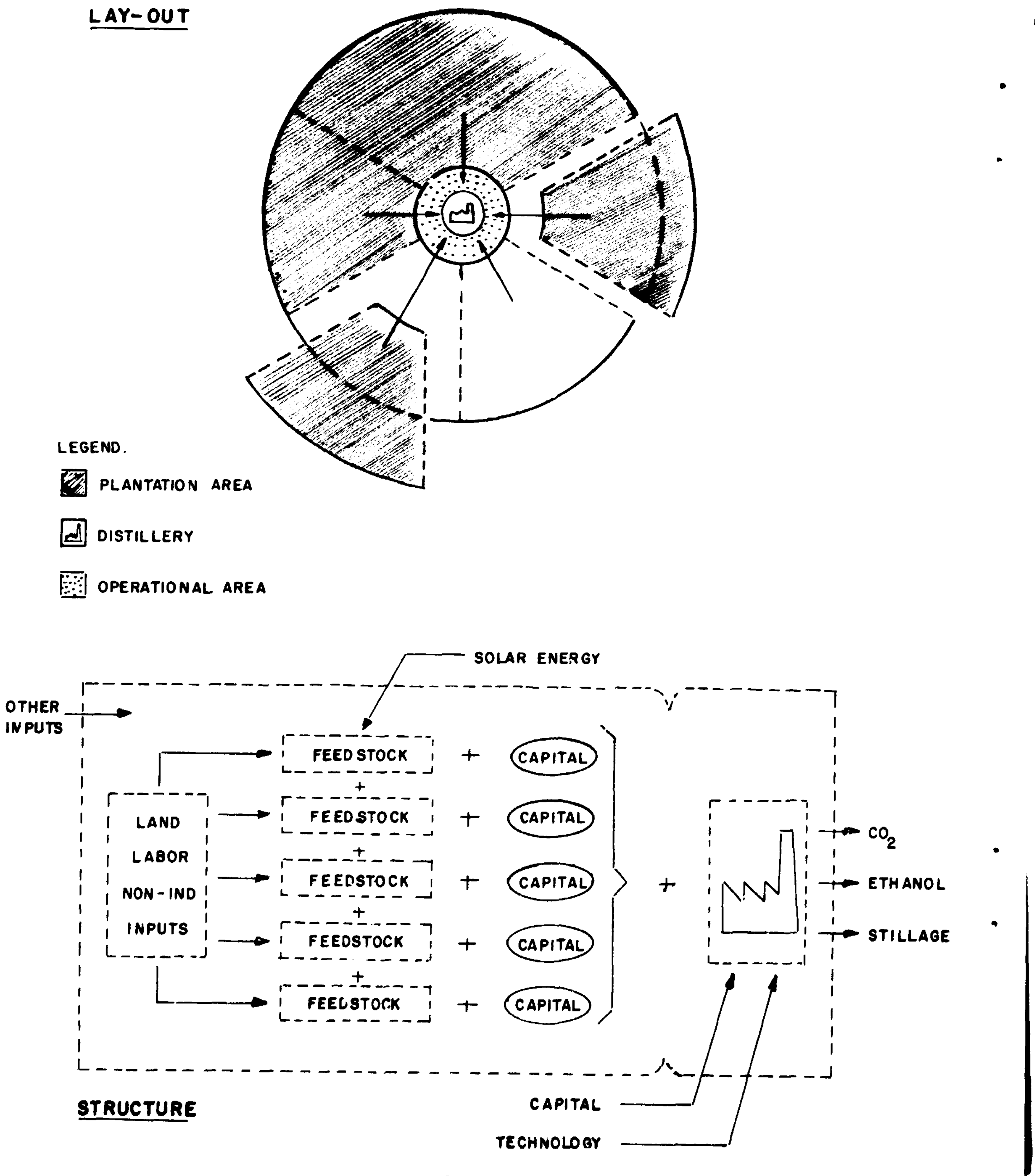




STRUCTURE

FIGURE 4

COOPERATIVE FEEDSTOCK SUPPLY SYSTEM



From the general agroeconomic point of view small scale distilleries present a series of advantages which make them attractive enterprises. Key points that can be emphasized are:

- Flexibility of the small scale units in relation to geographical location;
- Lower investment requirements;
- Alternative feedstocks;
- Lower volume of feedstocks.

Given the size range of these small scale systems they can be easily placed in most geographical scenarios. Also, barring edaphoclimatic restrictions, other crops such as sweet sorghum potatoes and others easier to manage on a small scale could provide alternative feedstocks.

Another point of concern is the system's energy balance. The energy balance of a fermentation ethanol production complex is almost entirely determined by the feedstock utilized. In the case of sugarcane and mandioca it is quite clear that the former has an excess of bagasse to produce the process steam and other energy needs. The latter, has not yet proved its complete self-sufficiency although use of stalks and leaves of mandioca coupled with methane derived from stillage fermentation may meet the process energy requirements.

Depending on the ratio between aerial part to root of mandioca, which varies from cultivar to cultivar, the system could be self-sufficient on stalks alone (Ref. 15).

Assuming conservatively that there will be a necessity of external sources of energy to produce mandioca ethanol, the required energy could be easily obtained from sources such as wood and agricultural wastes.

Another interesting aspect of the small scale agroindustrial systems is the possibility of utilizing the same feedstock in various forms. In the case of mandioca alcohol distilleries, for example, mandioca pellets and/or rasp, produced at the farm level, can replace the fresh roots.

This alternative enables:

- Elimination of the pellets drying at the distillery, a very costly process;
- Reduction of feedstock transportation costs per unit volume of alcohol produced;

- Increase in labor demand, generating more stable job opportunities.

- Reduction of fresh roots spoil, thus extending feedstock storage period.

For sugarcane agrosystems, sweet sorghum seems to be a good alternative for distillery operation in the period in between cane harvests.

4.2.2
Large Scale Systems

Agroeconomic aspects of large scale fermentation ethanol production are substantially different from those of small scale. On large scale it is no longer feasible to utilize the typical rural scenarios. An agricultural system specifically designed for fuel production is required. Thus, major structural transformations may have to occur in rural areas to implement large scale agroenergy production.

The aspects CTP identified as potential problems in setting up large scale fermentation ethanol production systems are: (Ref. 17).

- Ability to acquire the volume of feedstocks required for normal operation of a distillery;

- Need of a continuous supply of feedstock;

- Agronomic problems related to the production of a large and steady supply of feedstocks;

- Effect of oscillations in feedstock quality (sugar or starch content) on the cost of alcohol;

- Managerial, environmental, agronomical and technological capacity to respond to ethanol systems demands;

- Social and economic effects of large scale alcohol production.

Consequently the implementation of large scale agroenergy production systems requires identifying rural scenarios capable of responding adequately to the various inherent constraints.

This barrier becomes more difficult in developing countries. On the average they do not present neither the geographical extension nor the agricultural capacity to devote extensive areas to the production of energy crops. In this sense, Brasil represents a unique case which may not be valid elsewhere.

It is important to note that even in the Brasilian case, implementation of large scale distilleries has resulted in the short term in negative side effects from an environmental, social and economic point of view (Ref.18). Proalcohol is primarily based on sugarcane as a feedstock. Hence a noticeable geographical concentration has occurred in the State of São Paulo. Consequently, a serious ecological threat developed relative to disposal of stillage in streams (Ref. 19). Also, because of the socio-economic characteristics associated to large scale agroindustrial systems, an accentuation of land ownership concentration has occurred.

The expansion of sugarcane plantation at the expenses of food crop land have to a limited extent curtailed food crops supply.

It is important to realize that in a situation in which there is a relative scarcity of land, the prices of food will tend to be directly set by the price of fuel, barring Government intervention (Ref. 20; 21).

Table 7 shows approximate figures of plantation land requirements and production levels of raw material needed to support various sizes of large scale distilleries.

It is possible to implement highly mechanized processes for agricultural production as well as more efficient and secure production methods. On the industrial side, it is possible to utilize better materials and equipment increasing the plants productivity and durability. Both contributions may result in lower alcohol production costs.

In the case of large scale agroenergy systems, there is little room for alternative structural and organizational concepts. It is quite clear that both components, feedstock production and processing, have to be undertaken as integrated industrial activities. In Brasil, all large scale distilleries belong to private property. Their organizational and administrative structure is concentrated in the owners' hands, who generally control most of the agricultural production as well as the distillery operation. There are few cases of agricultural cooperatives. They operate on a closed system basis and their associates have heavy family links or form solid economic groups with diversified interests.

Some important aspects of the large scale distilleries are their dependence on hired labor, their financing scheme and government subsidies (see Appendix A-4) and their energy input requirements (see 4.4- Energy Analysis).

4.2.3
General Aspects

It is important to point out the major differences between the two key Brasilian alcohol feedstocks (sugarcane and cassava).

TABLE 7

LARGE SCALE AGROENERGY SYSTEMS LAND[(a)]
AND PRODUCTION REQUIREMENTS

- Annual Basis -

Crop		Capacities (m^3/day)		
		60	120	240
Cane Juice	Quantity (t)	161.2	322.4	644.8
	Land (ha)	3.0	6.1	12.2
	Ethanol Production ($10^3 m^3$)	10.8	21.6	43.2
Cane Molasses	Quantity (t)	36.0	72.0	144.0
	Land (ha)	18.0	36.0	72.0
	Ethanol Production ($10^3 m^3$)	10.8	21.6	43.2
Mandioca	Quantity (t)	132.0	264.0	528.0
	Land (ha)	10.2	20.3	40.6
	Ethanol Production ($10^3 m^3$)	19.8	39.6	79.2

Note:

(a) Only area harvested on a given year.

In either case, small and large distilleries, the utilization of sugarcane does not allow year round operation unless equipped with molasses storage facilities. Due to its edaphoclimatic requirements sugarcane is only harvested in Brasil during 7 months a year in the North/Northeast and 6 months in the Center/South. Evidently, soil and climatic conditions of each situation will determine different harvest periods. Table 8 shows a planting and harvesting schedule for sugarcane.

Sugarcane harvest has to be performed at peak maturation stage which lasts between two and three months. This optimum stage corresponds to highest sucrose content in the stalks.

Since different cane varieties mature at slightly different phases, it is possible then to extend the harvesting period up to 6/7 months without having to harvest plants too early or too late in relation to their optimum maturation stage.

Table 9 shows a planting and harvesting schedule for mandioca. Mandioca is resilient with respect to edaphoclimatic requirements. It is possible to plantmandioca during long periods of the year (average tropical conditions)*. Mandioca can be kept planted without loosing its starch content nor yield levels. However, it is important to identify mandioca varieties which better adapt to local conditions since starch content and/or yield could be considerably affected.

To emphasize the difference between sugarcane and mandioca Table 9 is based on establishing the same planting schedules for cultivars which are to be harvested in different cycles: early (10-12 month); medium (14-16) and late (18-20 month).

4.3 Industrial Processing

Industrial processes adopted in Brasilian distilleries for ethanol production based on sugarcane juice and molasses, and on mandioca are briefly described:

4.3.1 Sugarcane Independent Distillery

The block flow diagram shown in Drawing No. CT-UN01-01 presents the major processing steps required in the production of ethanol directly from sugarcane juice.

The process comprises three major processing phases:

. feedstock preparation
. fermentation
. distillation

(*) The major determinant is rain fal during plantation period.

TABLE 8

SUGARCANE HARVESTING SCHEDULE

REGION	PLANTING												HARVESTING																
MONTH	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
N/NE																													
C/S																													

NOTE: N/NE = NORTHERN/NORTHEASTERN REGION

C/S = CENTER/SOUTHERN REGION

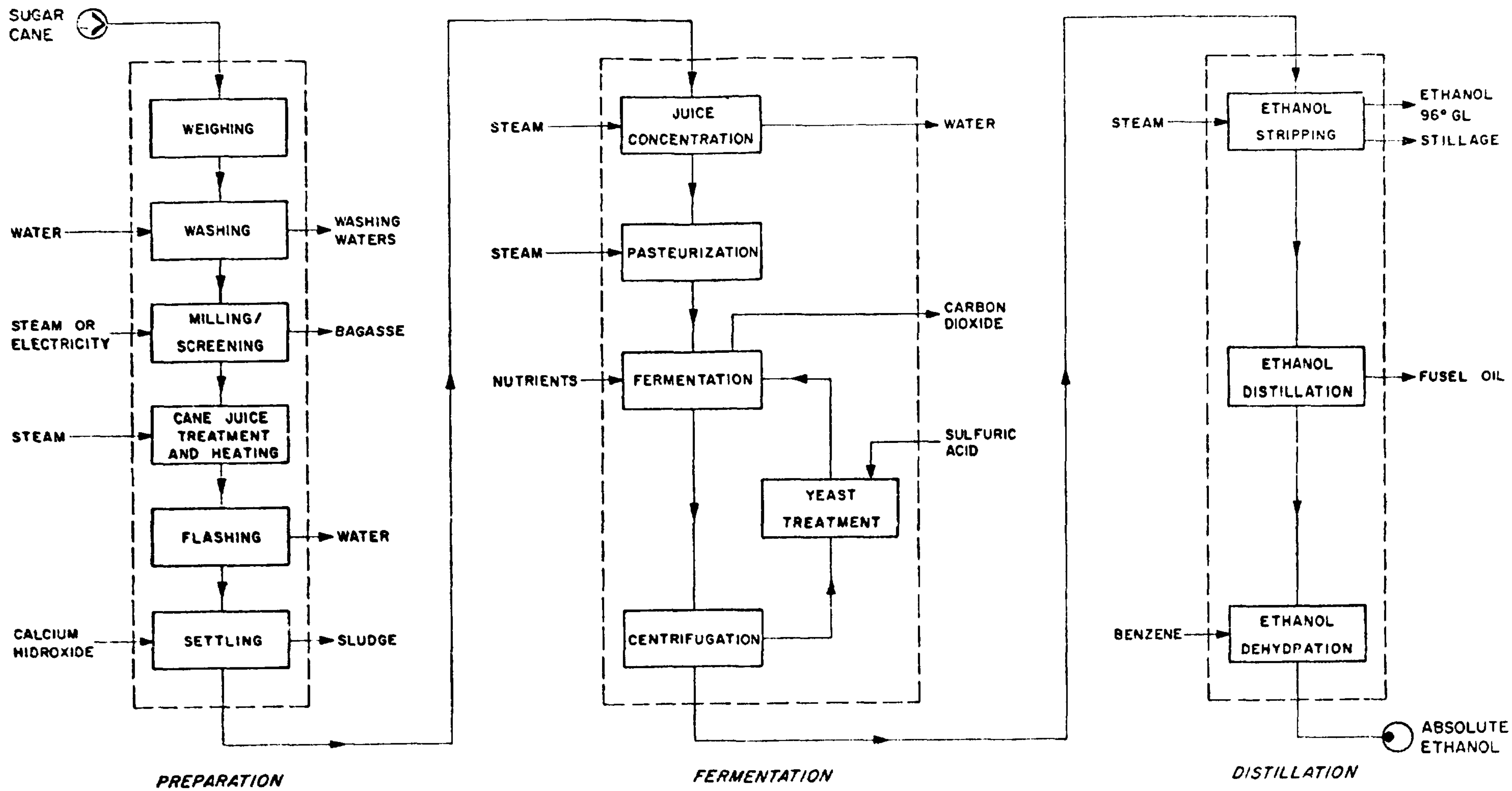
REF.:(22)

TABLE 9

MANDIOCA HARVESTING SCHEDULE

VARIETY TIME	PLANTING												HARVESTING															
MONTH	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
EARLY																												
MEDIUM																												
LATE																												

REF.: (23)



PROJECT: FERMENTATION ETHANOL PRODUCTION COST MODEL				
TITLE: ETHANOL FROM SUGARCANE JUICE: PROCESS FLOW DIAGRAM				
REV.	DWN.	DATE	CHK.	NO.
0	CB/PC	06. 05. 80	CB	CT-UN01-001

The preparation and distillation steps are continuous and based on physical operations. On the other hand, fermentation of sugarcane juice is batchwise and based on biochemical reactions.

Sugarcane is usually washed prior to crushing, in order to remove soil and other materials that might damage the roller surfaces. Sugarcane then is mechanically milled, i.e., passed through a series of toothed rollers in tandem that squeeze the juice out of the stalks. After a treatment with lime and heat, sugarcane juice is concentrated to adjust sugar concentration to 15^o Brix level and to reduced fermentation vats volume. The preconcentrated juice is then pasteurized to avoid growth of wild micro-organisms that would compete with yeast for available sugar and decrease ethanol yield.

Fermentation takes place through the action of yeasts in the treated juice under appropriate conditions to favor ethanol formation. The fermented wine is centrifuged and sent to distillation to separate ethanol from byproducts.

Preparation

The preparation phase of the process includes:

. Weighing of raw material.

. Sugarcane washing in order to remove soil and materials that can damage process equipment. Aclosed water system is used in canewashing, i.e., the washing waters are decanted in lagoons and recycled back to the system.

. Washed sugarcane stalks are cut through shredders to facilitate sugar removal from cellulosic cells in the following juice extraction step.

. In a sequence of toothed rollers, in tandem, the juice is squeezed out of the stalks. In order to increase sugar extraction efficiency hot water is added to the last mills. The bagasse thus produced, with 50% humidity, is used as a fuel for raising steam at the distillery.

. The removal of undesirable substances such as fibers, gums and waxes is done through chemical and thermal treatment of the juice. Hot liming causes the precipitation and sedimentation of some of these substances, producing a clarified juice.

Most of the energy required in ethanol production from sugarcane, is consumed in the preparation phase, mainly in the mill. Since bagasse is available at no cost, it is burned to raise steam used as the driving energy. Steam is produced at medium pressure ($15\ kg/cm^2$) aiming also at self-generation of electricity for the plant. Exhaust steam of both systems (mill and electricity generator) is the heat source for ethanol separation and other services.

Fermentation

Fermentable sugars content in sugarcane juice just after milling is approximately 12° Brix, i.e., 12% w/w. To produce a fermented wort or wine with an alcohol content of 7-8% v/v, a 15° Brix juice is required. Thus the concentration of the juice is then raised since ethanol separation equipment are designed for operating with a fermented wine with such an ethanol percentage.

Typical vertical evaporators, shell-and-tube type, concentrate the sugarcane juice up to 18-20° Brix using exhaust steam. The same type of evaporator is used in juice concentration for sugar production.

The pre-concentrated juice is pasteurized to avoid growth of undesirable microorganisms that will reduce ethanol yield. Such a process step is performed in a heat exchanger using steam as heating medium.

In the fermentation step, conversion of fermentable sugars into ethanol takes place in open fermentation vats. In Brasil, only batch operation is used in ethanol production.

Major items of equipment in this unit in addition to fermentation vats are: pumps, intermediate tanks, centrifuges and sulfuric acid tank.

Fermentation vats are initially charged with 1/5 of their volumes with 15° Brix juice. After adjustment of sugar concentration, pH correction with dilute sulfuric acid solution, and nutrients addition, sugarcane juice is innoculated with yeasts.

When carbon dioxide evolution starts vats are totally filled up with juice. To prevent contamination small amounts of antibiotic usually pentachlorophenol are added. Fermentation vats should be closed and provided with cooling system (internal coil or external heat exchanger) to maintain wort temperature during fermentation close to 32°C. Some advantages of anefficient removal of heat evolved are:

. Reduction in ethanol losses by evaporation

. Achievement of higher ethanol content in the wort

. Operation at optimum yeast metabolic conditions

. Reduced fermentation time.

Typical fermentation times are 12 to 18 hours. Completion of fermentation is indicated by wort density decrease. Ethanol contents of 7 to 8% v/v is consequently obtained. Yeasts are separated from the wort by centrifugation. Clean fermented wort is them pumped to the distillation unit from a hold tank. A sulfuric acid solution is added to the yeast milk lowering pH to 2.5. This treatment removes dead yeasts and other microorganisms not resistant to such low pH. Living yeasts are recycled to the process to another fermentation cycle (Melle Boinot process).

Distillation

Ethanol is separated from fermented wort through distillation, an energy intensive process. Figure 5 presents a typical flowsheet of an absolute ethanol distillation system using steam as the heating source. In the first column, called distillation column, ethanol is stripped from the wort by steam injected directly into the column.

The top stream is known as flegma, a binary mixture containing equal volumes of ethanol and water. The head product of the first column is hydrated ethanol (about 90% v/v) containing all volatile substances present in fermented wort. As shown in Figure 5, the flegma is fed into the rectification column where three streams are separated out: the top stream, containing 95.5% alcohol by volume or 95.5°GL (the ethanol-water azeotropic composition), called industrial alcohol; the bottom stream, called flegmass; and fusel oil, a mixture of organic compounds with a predominance of amyl alcohols.

The rectification column top stream feeds the dehydration column, where residual water is separated out through the addition of benzene.

The ternary azeotropic mixture (water/alcohol/benzene) formed at the ratio of 7.5:18.5:74%, on volume basis, has a boiling point (65°C) lower than absolute alcohol, which allows the latter to be obtained as a bottom stream from the dehydration column. The unit also includes a fourth column for benzene recovery and consequent production of low-grade industrial alcohol. This stream is sent back to the rectification column for ethanol recovery.

In some Brasilian distilleries, glycerol is still used instead of benzene as the dehydrating agent, while cyclohexane or ethyl ether, which are less toxic than benzene, are used in other countries.

Table 10 shows a typical material balance for an absolute alcohol distillation unit. The streams indicated correspond to those shown in the diagram on Figure 5.

4.3.2
Sugarcane Molasses Distillery

In sugar production, sugarcane juice is chemically treated and concentrated in multiple-effect evaporation systems where crystallization of the sugars occurs. Next, centrifugation separates the crystallized sugar from molasses, which contains as much as 60% (w/w) total reducing sugars.

<u>FIGURE 5</u>

TYPICAL FLOWSHEET OF AN ABSOLUTE ALCOHOL DISTILLERY

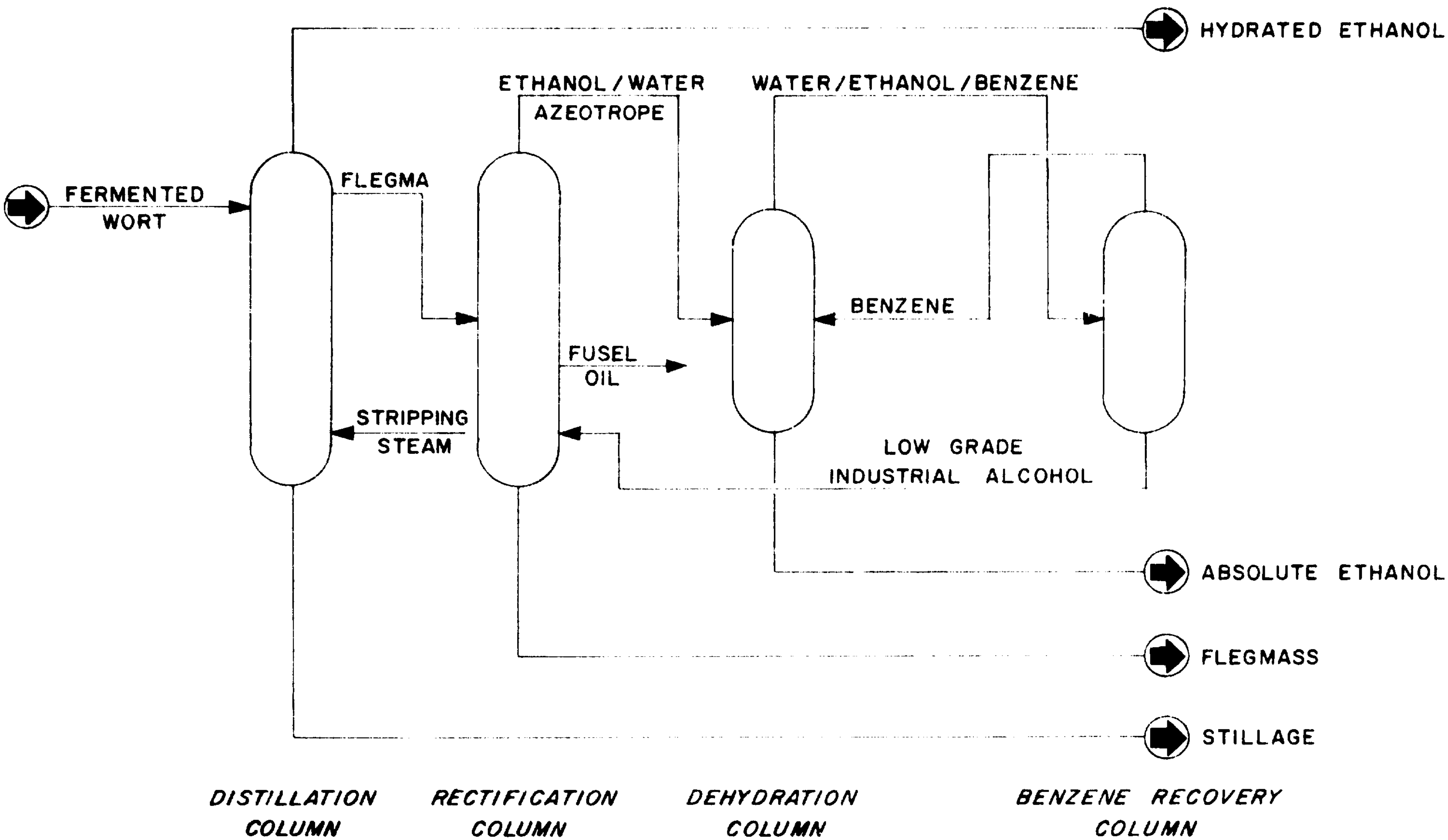


TABLE 10

TYPICAL MATERIAL BALANCE OF AN ABSOLUTE ETHANOL DISTILLATION SYSTEM IN BRASIL

BASIS: 1 m^3 of Absolute Ethanol

Stream	Unit	Flow	Ethanol Content (% vol.)
Fermented Wort or Wine	m^3	14.3	7-9
Flegma	m^3	2.0	50.0
Hydrated Ethanol	m^3	0.05	90.0
Stripping Steam	t	2.0 - 2.5	-
Ethanol/Water Azeotrope	m^3	1.1	95.5
Benzene	m^3	0.5	-
Azeotrope Water/Ethanol/Benzene	m^3	0.6	18.5
Flegmass	m^3	1.0	-
Fusel Oil	ℓ	1.0	-
Stillage	m^3	13	0.1 - 1.0

Ref.: (24)

Since molasses has a high sugar concentration it can be stored for longer periods without attack by microorganisms. Therefore, storage of concentrated sugarcane juice during harvest to be processed in the off-season period extends the operating period of independent sugarcane distilleries and consequently could increase their profitability.

The process for molasses fermentation into ethanol comprises three steps:

. mash preparation

. fermentation

. distillation.

Drawing No. CT-UN01-02 presents a simplified block flow diagram of this process.

In the mash preparation steps, molasses is diluted with process water or sugarcane juice diverted directly from the mill. In this case, mash pasteurization is required.

The practice of diverting sugarcane juice for molasses dilution has been adopted in Brasilian annexed or byproduct distilleries whenever sugar prices are down or when the sugar mill reaches its authorized sugar quota before the end of the harvest season.

The other steps of ethanol production from molasses are similar to that of sugarcane juice described previously.

4.3.3
Mandioca Independent Distillery

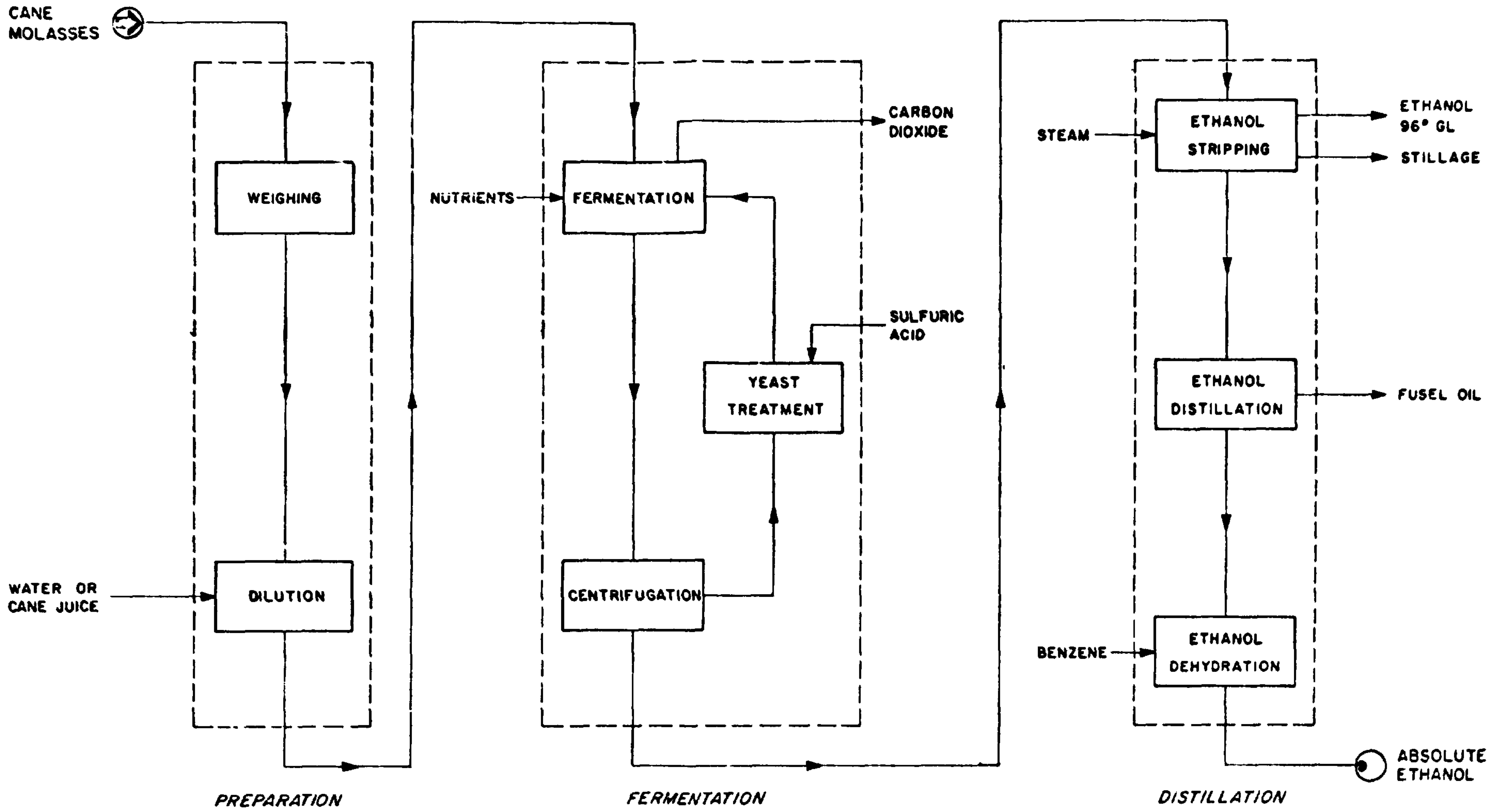
Brief Description

The block flow diagram shown in Drawing No. CT-UN01-03 illustrates the major processing steps required to produce absolute ethanol from mandioca roots.

The process comprises four major processing phases, which are:

. mash preparation
. conversion
. fermentation
. distillation

Mash preparation and distillation phases are continuous and are based on physical operations. Conversion and fermentation phases are based on batch biochemical reactions, although recent development work demonstrate the feasibility of continuous operation.



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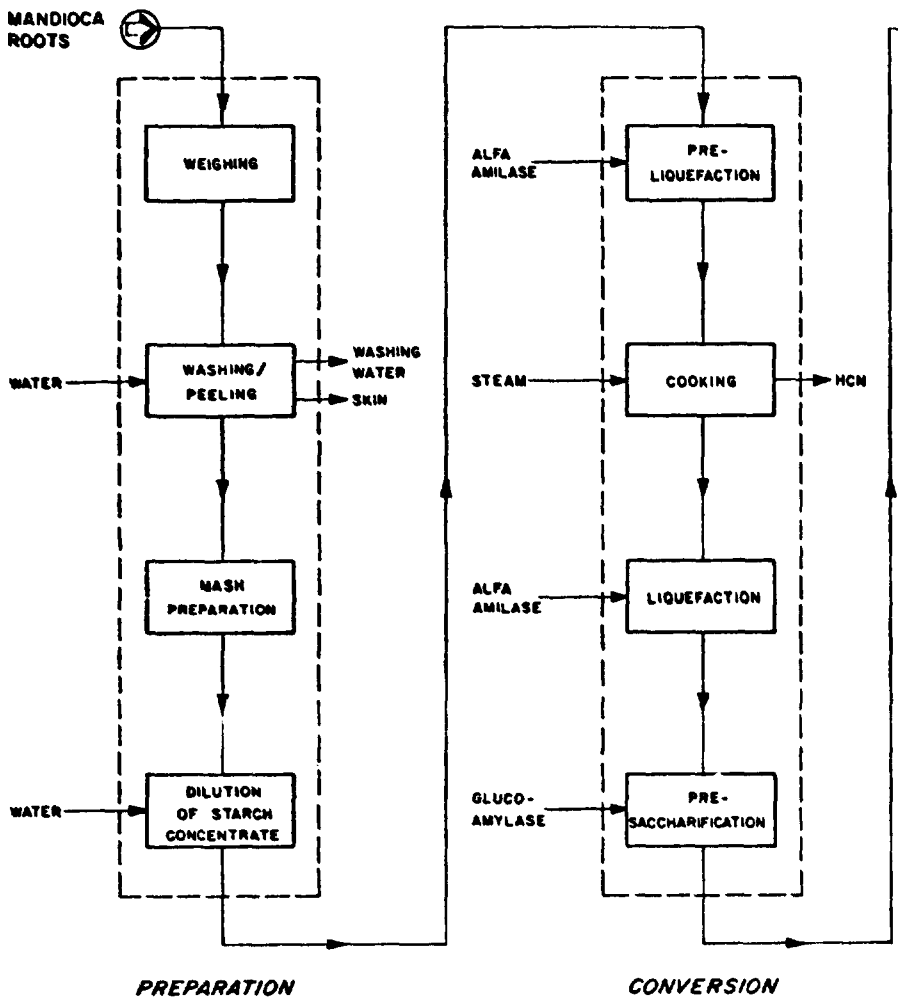
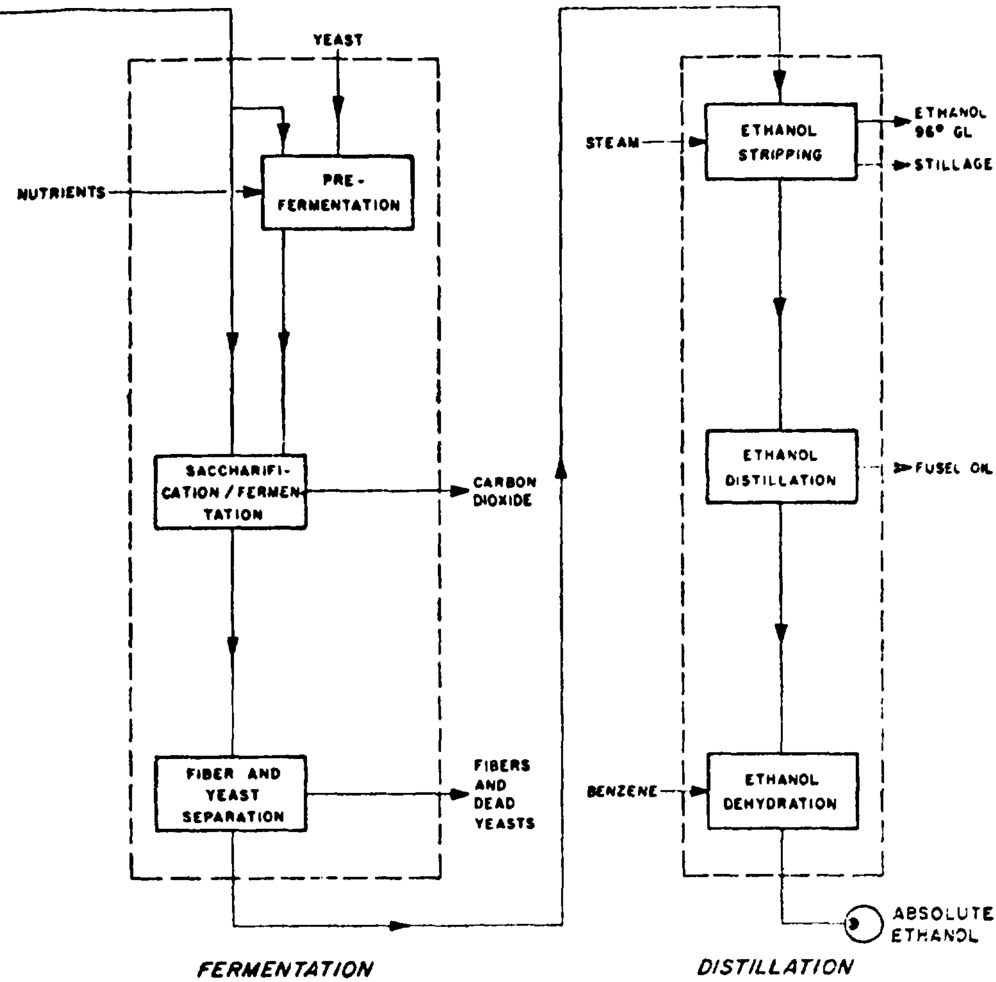
TITLE: ETHANOL FROM SUGARCANE MOLASSES: PROCESS FLOW DIAGRAM				
REV.	DWN:	DATE:	CHK:	NO.
0	CB/PJ	05. 05. 80	CB	CT-UN01-002


MANDIOCA ROOTS
WEIGHING
WATER
WASHING/ PEELING
WASHING WATER
SKIN
MASH PREPARATION
WATER
DILUTION OF STARCH CONCENTRATE
PREPARATION
ALFA AMILASE
PRE-LIQUEFACTION
STEAM
COOKING
HCN
ALFA AMILASE
LIQUEFACTION
GLUCO-AMYLASE
PRE-SACCHARIFICATION
CONVERSION



PROJECT: FERMENTATION ETHANOL PRODUCTION COST MODEL				
TITLE: ETHANOL FROM MANDIOCA: PROCESS FLOW DIAGRAM				
REV.	DWN.	DATE	CHK:	NO. CT-UN01-003
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In the mash preparation phase, fresh mandioca roots are initially washed and peeled in order to remove skin and mud. The clean roots are then reduced in size through a combination of chopping and grinding. Water is finally added to the desintegrated roots resulting in an aqueous suspension called crude mash.

Part of the starch present in the crude mash is converted into sugars in the conversion phase, through a combination of heat and enzymatic action. Initially, the crude mash is cooked with steam in order to prepare the starch granules for subsequent enzymatic action. Breakdown of starch molecules is achieved through combination of alpha-amylase action(in the liquefaction step) and glucoamylase action (in the pre-saccharification and saccharification steps).

Fermentation takes place through a yeast culture in saccharified mash medium, under appropriate conditions to favor ethanol formation. The fermented wort obtained at the end of fermentation reaction contains alcohol and some suspended solid residues. These residues (mainly cellulosic fibers and dead yeasts) are removed prior to distillation of the fermented wort.

In the distillation phase, ethanol, stillage and other byproducts are obtained.

Dried mandioca chips, pellets or rasps are alternative feedstocks for the distillery concept described.

Experience from mandioca-starch industries have shown that dried mandioca chips with a maximum water content of approx. 10% can be stored during long periods of time without losses due to deterioration, as observed for fresh mandioca roots. (Ref. 15).

Storage of dried chips enables operation of the distillery in the event of temporary interruption of fresh mandioca roots supply. In addition, dried chips can be mixed with fresh mandioca roots to increase the average starch content of the ground roots used for crude mash preparation. This procedure enables partial dampening of expected variation in the starch content of fresh mandioca roots over the year.

Controlled addition of dried chips into the ground mandioca root stream assures a close to constant starch concentration and mass flowrate of the crude mash.

The drying of mandioca chips can be performed at the distillery or at the farm level (in this case solar drying is used). Adoption of the latter alternative would reduce raw material transport cost. Drying at the distillery would increase fixed investment.

The chip drying system (considered as a package unit), includes blower, cyclone and conveying screws; dried chip silo, elevators and pneumatic transportation system.

The drying system should operate intermittently following the suggested operating procedures stated previously. The frequency of operation of this system depends on the frequency of failure in fresh mandioca supply and on the profile of the starch content of the roots along a year.

Mash Preparation

In the mash preparation unit, fresh mandioca roots are washed, peeled and desintegrated. The purpose of these operations is to prepare the roots for enzymatic starch hydrolysis in the subsequent steeps.

The major items of equipment of this unit are: washer-peelers, root choppers, grinders, distributors, elevators, conveyors, screws, tank and pumps for the crude mash. Crude mash is an aqueous suspension of desintegrated roots, containing approximately 16% (wt) of starch and 19% (wt) of total solids, which is sent to the conversion step.

Fresh roots from the deposits are transferred to the washer-peelers through belt conveyors. Wash water is added in the washer-peelers to remove mud carried by the roots. Mud is separated from mandioca skin which can be press-dried and transferred to the boilers for burning.

Clean mandioca roots are sent to the choppers and then to the distributors, from where they are fed to the grinders. The ground roots should have a length of approx. 0.1-0.5 mm and are transferred through conveyors to the crude mash tank. Alpha-amylase enzyme and process water for hydrolysis are added in this tank.

The quantity of process water added for hydrolysis is a function of the average starch content of the roots being processed and the level of absolute ethanol production. The starch concentration in the crude mash can be maintained close to constant by proper adjustment of the flowrate of process water for hydrolysis.

Conversion

Conversion consists of 3 consecutive batch steps which enable the crude mash to be converted into a fermentable wort. These steps are: cooking, liquefaction and pre-saccharification.

The major items of equipment of this unit are: cookers, liquefaction vessels, pre-saccharification vessels, expansion vessels, heat exchangers and pumps.

The continuous jet cooking of the crude mash with true steam through an injector is a technically feasible alternative. Besides lowering cooking temperature to 105°C a homogeneous starch suspension is obtained. In addition to these advantages, reduction in investment and utility (steam) consumption will result from the use of jet cooking.

During the cooking step, hydrogen cyanide originally present in mandioca roots is liberated.

At the end of the cooking cycle, the cooked mash is discharged into an atmospheric expansion vessel. This operation serves to cool the mash, before transfer to the liquefaction vessels, to a temperature within the range of optimum activity for the enzyme alpha-amylase. In so doing, flash steam is recovered and can be used for preheating the feed (crude mash) to the cooker. Also hydrogen cyanide can be vented off the system.

Liquefaction takes place at a temperature of 90°C and a pH of 6.5 with the addition of alpha-amylase enzyme in the liquefaction vessels. Average contact time of the cooked mash with the enzyme is of the order of 40 minutes. Any pH adjustment required is made through controlled addition of dilute solution of sodium hydroxide.

Batches of liquefied mashes are next transferred to the pre-saccharification vessels. Pre-saccharification takes place through the addition of glucoamylase enzyme, at a temperature of 60°C and a pH of 4.0. Average contact time of a batch with the enzyme is of the order of 40 minutes; pH adjustments are made through controlled addition of dilute solution of sulphuric acid.

Fermentation

In this unit, conversion of the pre-saccharified starch into sugars takes place concurrently with the fermentation of sugars into alcohol in fermentation vats.

Batch saccharification and fermentation are carried out in the fermentation vats. Experimental results have indicated that saccharification is the rate-limiting reaction (Ref. 25).

The major items of equipment in this unit in addition to the fermentation vats are the following: culture vessels, prefermentors, filtration system, sterile air generation unit and pumps.

The fermentation vats should be closed vessels provided with internal cooling coils with adequate surface area to maintain the temperature of the wort during fermentation close to 32°C.

Fermentation vats are initially charged with yeast cultures up to 1/5 of their volumes. They are next filled with pre-saccharified mash transferred from the conversion unit. At the end of the fermentation cycle, each batch is transferred to one of the two stand-by vats, from where the fermented wort feeds the vacuum filtration system. In this system, solid residues (mainly mandioca cellulosic fibers and dead yeasts) are separated from the fermented wort . Clean fermented wort is then pumped to the distillation unit from a hold tank. Solid residues from the filter should be press-dried to 50% H_2O content, in order to reduce alcohol losses. This residue can be added to stillage to improve methane yield in anaerobic fermentation. Yeast culture to initiate the fermentation batch cycles should be developed in two steps. Inoculum is first added to the culture vessels, in a water medium containing molasses and some micronutrients (superphosphate and ammonium sulphate solutions).

When the concentration level of the nutrients has fallen to very low levels due to consumption by the growing yeast population, the contents of a culture vessel are transferred to a prefermenter vessel. The second step in the yeast culture cycle takes place in the prefermenters by completing their partially empty volumes with pre-saccharified mash. The prefermentation cycle time is estimated at 36 hours.

Upon completion of the prefermentation cycle, half of the batch shall be transferred to the vats to initiate the fermentation cycle. The half-full prefermenter is next filled with pre-saccharified mash setting off a new prefermentation cycle.

Special attention should be given to possible contamination problems which can disturb the fermentation process and cause losses of entire batches. Production of alcohol from mandioca is expected to be more contamination-prone than from sugarcane due to the longer fermentation time required and thus a lower average alcohol concentration in the wort.

Distillation

The filtered mash is sent to the distillation unit where the various components of the fermented wort are separated. The same system, described previously, is used to separate ethanol and other byproducts from the fermented wort.

4.3.4 Material and Energy Balances

The material and energy balances for ethanol production from sugarcane juice and molasses and from mandioca are presented here. Figures reflect current technology prevailing in Brasilian distilleries and CTP/PROMON expertise in process design of ethanol producing systems.

Table 11 shows all physical inputs and outputs of the agricultural sector of the system. The byproducts or annexed distillery was not considered in this analysis since molasses has already assigned a selling price or a transfer cost (for distilleries attached to sugar mills). In Brasil, sugarcane price is administered by the Government's IAA - Sugar and Alcohol Institute and is supposed to provide farmers a reasonable return on investment.

Table 12 presents material and energy balances for the production of 1 m^3 of absolute ethanol. The values shown in Table 12 are valid within 30% error margin for the range of capacities considered in this report. It is evident that for a small scale distillery, producing 5 m^3 of absolute ethanol per day, the efficiency of each process step is lower than that of large scale units. Bases for material and energy balances are shown in the notes of Table 12.

4.3.5 Future Technological Innovations

Under state-of-the-art technology and for the various feedstocks fermentation alcohol production is only economically feasible at subsidized prices. Considerable improvements in the process technologies are required to achieve subsidy-free economic fuel alcohol production.

Technological innovations will play a decisive role in large scale alcohol production more than in the small scale. Agricultural technology innovation is by far the key to successful economic production of fuel alcohol. Overall the criterion of opportunity cost should prevail. In the fuel alcohol context this translates into alternative markets and prices for ethanol agricultural feedstocks, as well as gasoline prices.

Agroeconomic Aspects

Agricultural subsystems account for over 50 percent of total alcohol production costs (Ref. 17). Hence alcohol production feasibility is highly sensitive, and therefore vulnerable to the efficiency of its agricultural subsystems. In fact, experience shows that the major current problem of fermentation alcohol production, particularly on large scale, is the lack of a sufficiently productive agriculture capable to supply feedstocks at the rate required for economic operation of the distilleries.

In the Brasilian case, efforts have been made to improve the agricultural subsystems. However, there is still a long way to go.

TABLE 11

INPUTS AND OUTPUTS TO AGRICULTURAL SYSTEMS FOR ETHANOL PRODUCTION

BASIS: 1 m^3 absolute ethanol

Item	Unit	Value	
		Cane Independent Distillery	Mandioca Independent Distillery
Feedstocks			
. Sugarcane	t	15	-
. Mandioca roots	t	-	6.67
Fertilizers			
. Ammonium Sulfate	kg	121	63
. Potassium chloride	kg	24.5	15
. Super Phosphate	kg	10.5	7.5
Inseticides	kg	0.11	10
Herbicides	kg	0.7	-
Electricity	kWh	-	0.6
Diesel oil	10^{-3} m^3	60	45.2

TABLE 12

MATERIAL AND ENERGY BALANCES OF FERMENTATION ETHANOL PRODUCTION FROM SUGARCANE AND MANDIOCA

- INDUSTRIAL SECTOR -

BASIS: 1 m^3 OF ANHYDROUS ETHANOL

ITEM	UNIT	VALUE PER TYPE OF DISTILLERY		
		MOLASSES DISTILLERY	CANE INDEPENDENT DISTILLERY	MANDIOCA INDEPENDENT DISTILLERY
FEEDSTOCK				
CANE MOLASSES (a)	t	3.33	—	0.006
SUGAR CANE (b)	t	—	15.00	—
MANDIOCA ROOTS (c)	t	—	—	6.67
PROCESS INPUTS				
YEAST	kg	—	—	0.40
SUPERPHOSPHATE	kg	22.7	22.7	22.70
AMMONIUM SULFATE	kg	22.55	22.55	22.55
PENTACHLOROPHENOL	kg	0.4	0.4	0.44
SULFURIC ACID	kg	30	30	0.10
SODIUM HYDROXIDE	kg	—	—	2.93
BENZENE	kg	0.9	0.9	0.90
ALPHA - AMYLASE	kg	—	—	1.26
GLUCOAMYLASE	kg	—	—	3.42
UTILITIES				
CLARIFIED WATER	m^3	11.0	—	22.0
COOLING WATER (d)	m^3	5.2	8.0	5.3
BOILER FEEDWATER (d)	m^3	—	6.7	4.2
STEAM	t	4.5	7.0	6.1
ELECTRIC POWER (g)	kWh	—	—	448
COMPRESSED AIR	m^3	80	80	83
FUEL	t	—	3.9	1.7 (h)
PRODUCTS AND BYPRODUCTS				
HYDRATED ETHANOL (e)	kg	41.6	41.6	41.6
FUSEL OIL	kg	4.8	4.8	4.8
STILLAGE (f)	m^3	13	13	13
CARBON DIOXIDE	kg	760	760	760
HYDROGEN CYANIDE	kg	—	—	0.3 - 1.7
FIBERS	kg	—	700	340
MUD	kg	—	470	137.6

NOTES:

(a) CANE MOLASSES CONTAINING 550 Kg OF TRS (TOTAL REDUCING SUGARS) PER TON

(b) TOTAL SUGAR CONTENT: 12.5% w/w

(c) STARCH CONTENT: 25% w/w

(d) MAKE-UP FLOW = 4% OF CIRCULATION FLOW RATE

(e) 96 °GL = 192 PROOF

(f) ETHANOL CONCENTRATION IN FERMENTED MASH 8% v/v

(g) FROM ELECTRICITY UTILITY SYSTEM

(h) WOOD WITH 35% HUMIDITY; BOILER EFFICIENCY 70%

The following aspects have been identified as key improvements required in agriculture for fuel alcohol production:

. Increase in the quality, resistance and yields of feedstocks obtained through:

  - implementation of better agricultural production techniques (cultivation patterns, fertilizing methods, agricultural defensives, others);

  - genetic improvement of the feedstocks plants;

  - phytopathologic and taxonomic research to identify the pests and diseases that attack feedstock plants and possible prevention and control methods.

. Increase of agricultural productivity and improvement of agricultural production economics obtained through:

  - development of elaborated agricultural production schedules, land rotation schedules and patterns;

  - assessment of the agroeconomics of different feedstocks (geographic suitability, geographical availability of inputs, edaphoclimatic studies, economic elasticities, opportunity costs and market distortion analysis, etc.);

  - drastic improvement of infrastructure (transportation, health services, education, etc).

Industrial Aspects

Admittedly the industrial know how for fermentation alcohol production is quite established. In the case of sugarcane the technology has long years of utilization. It is however conventional in the sense that it has not changed even in recent years. In the case of mandioca, much has been done, particularly over the last few years. In the case of other sources such as sweet sorghum, potatoes, babassu and others, there is some accumulated experience particularly with respect to potatoes. Such technologies are already conceptually elaborated, however not yet tested commercially, except for potato alcohol as a source of potable alcohol. There is however still room for technology improvement

Key problems requiring improvement are the following:

. Batchwise operation. The various processing steps distillation excluded, are still batchwise. This results in lack of homogeneous product, efficiency losses, longer residence times, all of which reflect on equipment idle time, high energy consumption, etc.

. High cooking temperature, well above the required for other processing steps, resulting in considerable energy waste;

. Longer residence time for saccharification and fermentation in the case of mandioca (approximately 72 hours) characteristic of batchwise operation;

. Loss of alcohol, in the case of mandioca, due to removal of suspended solids before distillation.

. Consumption of imported purified enzymes in the starch conversion into fermentable sugars.

The principal innovations required to develop a modern concept of fermentation alcohol production are:

. Thoroughly continuous process which includes the cooking, dextrinization, saccharification and fermentation steps, in the case of mandioca or any starch containing feedstocks;

. Optimization of operational parameters of the various processing steps;

. Recycling part of the produced stillage to adjust feedstock concentration as well as to diminish the stillage output and increase alcohol production;

. Optimization of fibers treatment and separation methods;

. Anaerobic digestion of stillage yielding methane to be burned to raise process steam; and

. Immobilization of dextrinization and saccharification enzymes in a porous bed, seeking a drastic reduction on their consumption in the case of starch containing feedstocks (e.g. mandioca).

4.4 Energy Analysis

In broad terms, energy analysis is concerned with determining energy flows in processes of production of goods and services in the context of a pre-defined set of conventions. It constitutes a powerful tool in the formulation of energy policy of public and private entities.

In terms of national energy policies, energy analysis could contribute to:

. Improve national economic models and planning;

. Estimate energy requirements (present and future) of goods and services;

. Evaluate the effects of technological innovation and energy conservation, and stimulate the development of novel technologies.

Energy analysis could operate in three levels, namely:

. Introducing physical variables (energy) into economic theory;

. Identifying physical limits of production systems, to estimate the gap between the current situation and the theoretical ceiling;

. Establishing marginal cost parameters to facilitate resource allocation analysis between alternatives.

In practical terms, energy analysis could be extremely useful in the following areas:

. Energy conservation
. Non-conventional energy analysis
. National energy policy formulation.

The final fuel use of ethanol underscores the fact that the energy balance of the production system should in practical terms show a positive balance. In other words, the system should be a net generator of energy in the sense that the energy contained in the product should exceed the total energy invested in its production.

Solar energy is obviously the major input stream, but should not be computed in the balance as well as carbon dioxide because they are freely available. The consumption of energy associated with other input streams such as fossil fuels used in the production of fertilizers and agricultural pesticides must, however, be included in the assessment.

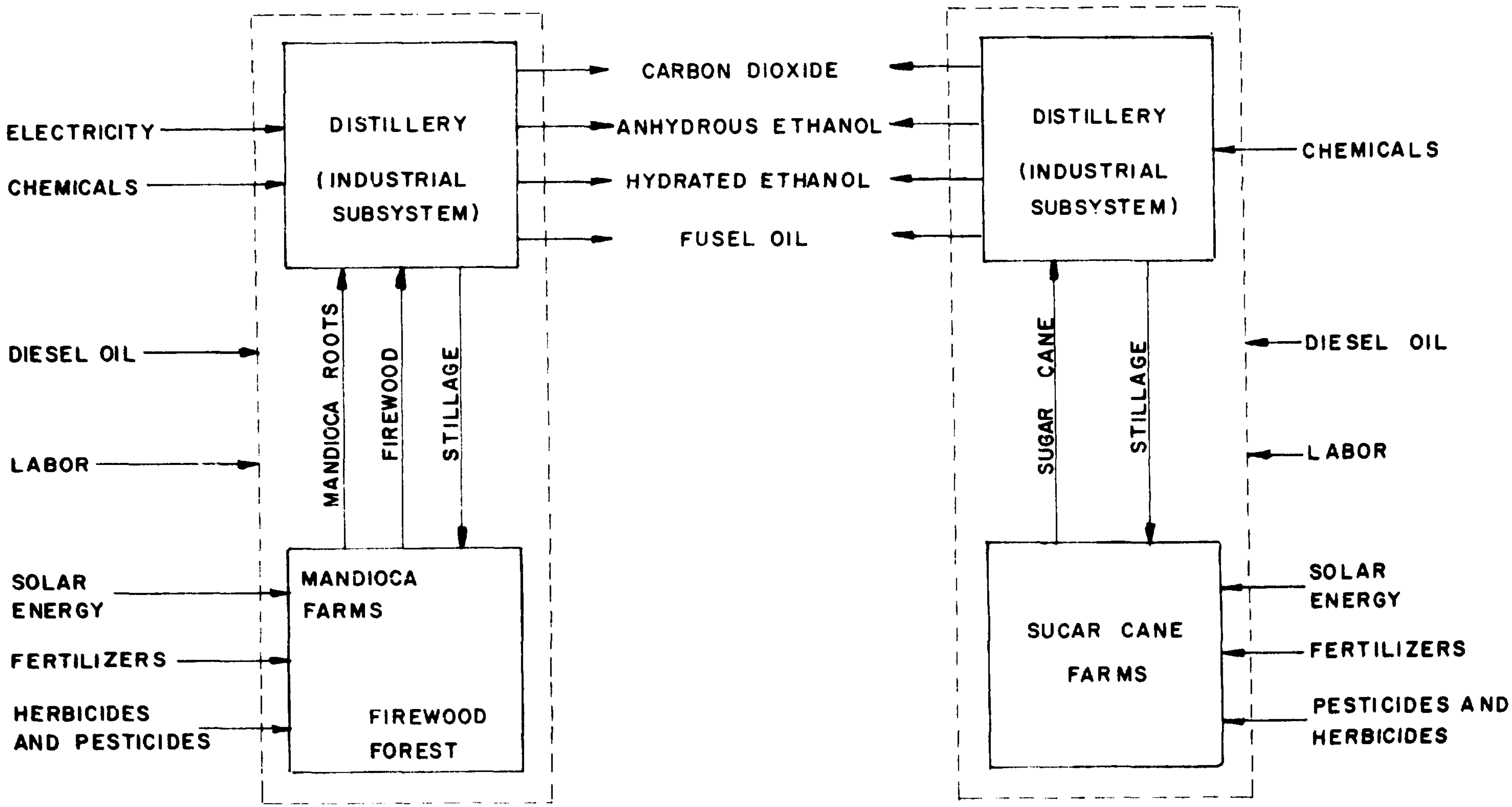
An useful tool in analysing energy conversion process like ethanol production is the <u>net energy ratio</u> - NER, defined as the ratio between the energy content of streams leaving a production system with previously established boundaries (outputs) and the energy content of streams entering the system (inputs) (Figure 6).

$$NER = \frac{\text{Energy content of outputs}}{\text{Energy content of inputs}}$$

In practical terms, NER analysis corresponds to an energy cost-benefit analysis of a given process, i.e., an evaluation of the return on the energy invest in the process.

FIGURE 6

FERMENTATION ETHANOL AGROINDUSTRIAL SYSTEMS CONFIGURATION
FOR NER ANALYSIS



The NER was computed for boundaries including only the distillery and the cane or mandioca plantations and for wider boundaries including also the forest supplying the firewood in the case of mandioca distillation systems, as shown in Figure 6.

Sugarcane and mandioca ethanol producing agroindustrial systems are equivalent in terms of energy (NER = 4.5). Exclusion of the system's woodlands from the calculation drastically reduces the NER for alcohol from mandioca (NER = 1.0).

On the other hand, the agroindustrial complex encompassing the cane farms, the sugar mill and the molasses distillery, presents the most favorable energy output (NER = 9.0).

NER analysis can help identify opportunities for overall improvement in energy conversion systems. However it has little value in deciding among alternative energy producing systems, since among other things NER depends so much on the particular boundaries selected for the system under study.

In spite of its imperfections and difficulties economic analysis employing social prices and discount factors still is the best tool for decision making in the evaluation of energy conversion projects.

4.5 Social, Economic and Environmental Impacts

A brief analysis of social, economic and environmental impacts of ethanol production is developed here. Although already described in technical terms, large and small scale distillery concepts will be analyzed from the social view point.

4.5.1 Description of Distillery Scale Concepts

Besides the technical definition of production scales - as referred to equipment and facilities size - it is interesting to develop qualitative distillery scale concepts. Given typical socio-economic and political structures of developing countries there is a wide gap among groups and region in their resources (financial, managerial, etc.). The rural areas, in particular, are a good example of this gap. Most developing nations do have hierarchized rural socio-economic patterns. Consequently, small distilleries are likely to be implemented with limited economic, environmental and technological resources. In contrast large scale distilleries are likely to be implemented with more abundant resources. Evidently, this implies the co-existence of different production concepts.

4.5.2 Small Scale Systems

Small scale distilleries are characterized by low investment requirements; ready access to feedstock supply; simple operational and management schemes; short implementation periods; incorporation of small farmers and local labor resulting on direct impact on income distribution, land ownership, employment, etc.

In Brasil, for instance, small scale distilleries are highly valuable since they could bring and disseminate energy production and economic activity in the interior of the country. On the other hand, interlinking scattered small scale distilleries with national alcohol storage, distribution and consumption systems could present problems. Consequently, their alcohol production may not directly participate in the national ProAlcohol context. They could supply localized demands for transportation, generation of electricity, irrigation projects and other local energy necessities.

It should be emphasized that, in Brasil, small distilleries could contribute to a better spatial distribution of fuel alcohol supply cutting fuel transportation costs resulting from high concentration of large scale distilleries. In addition micro/mini distilleries seem to have a greater socio-economic benefit/cost ratio and consequently should be considered as a powerfull tool for rural development.

Small scale distilleries are then not to be seen only as commercial undertakings and in this context should receive strong financial and institutional support as well as technical assistance.

Brasil, however, is certainly unique among other developing nations. Smaller countries with substantially less agricultural potential could however benefit from the small scale distillery alternatives. A system of integrated small units is more likely to reflect the country's feedstock production capacity. It would also have a smoother impact on other agricultural activities. It would be reasonable to expect that prime agricultural areas will be already committed to food production, export crops, etc.

In both cases, large and small countries, the implementation of small scale distilleries should contribute to diversify the base of agricultural resources to be used for fermentation alcohol production. It is not interesting to concentrate fermentation alcohol production around one specific crop since that would generate a highly vulnerable energy supply system. On one hand there will be the hazards affecting agricultural production. On the other hand, a dangerous dependence on crops that might have alternative markets and prices. Brasil serves as a reference show-case. Most fermentation alcohol production is based on sugarcane industry, which represents strong economic groups, with political influence. Alcohol production has the opportunity cost of sugar and molasses production and export. Historically alcohol production and use have been employed as a hedge against international fluctuations in sugar prices. In contrast there are not so obvious opportunity costs for small cassava distilleries, and other crops such as sweet sorghum, babassu, potatoes, etc. that could be incorporated into biomass energy programs. The alternative crops mentioned above will vary from country to country, however opportunity cost and socio-economic effects should be similar.

4.5.3
Large Scale Systems

The macro-distilleries requirements differ from those of smaller distillery sizes. They are characterized by the necessity of large investments, complex operational and management schemes, rigid operation schedules - relative to production and supply of the feedstocks - high degree of instrumentation, etc. which, all together, make macro-distilleries relatively inflexible sitewise. Macro-distilleries could benefit from economies of scale and through improved technology they could considerably increase productivity. Macro-distilleries are definetely commercial operations. From the social point of view large scale distilleries could improve local employment situation. However, their overall social benefits/cost ratio could be smaller than that of micro-mini distilleries.

4.5.4
Global Analysis

The major social and economic effects of alcohol production are creation of jobs, increase in rural incomes, promoting dynamic growth in rural areas with corresponding benefits in regional development, decrease in urban migration and the qualitative and quantitative raise of standards of living in rural areas.

The difference in quantifying social benefits result from the fact that the real extent of benefits depend very much on the energy crop (see 4.1.1 and 4.1.2) utilized, on the organization of the agricultural production, on the technical characteristics of the distilleries (technical coefficients of labor/capital), on the socio-economic environment where agroindustrial complexes are settled (see 4.2.2) and on various factors which altogether define a highly uncertain scenario. Nevertheless, some estimates have been made, for example, the Brasilian ProAlcohol is expected to create almost 600,000 new jobs (largely rural) by 1985.

The production of energy based on agricultural resources will have different effects upon various systems structures. These effects can be grouped in seven categories: Energetic; Economic; Social; Political; Technological; Ecological & Environmental and Spatial. Figure 7 shows these seven groups, pointing out their respective principal effects.

4.6
Distillery effluents: Handling and Uses

The major effluents of alcohol industry are aqueous. Water is used mainly for feedstock and equipment washing, raising steam and in cooling systems. In almost all uses water is contaminated with soluble and insoluble materials.

Among the waste waters generated in sugar mills and corresponding molasses distilleries, as well as in sugarcane and mandioca independent distilleries, stillage contains the highest pollution load in terms of organic material and mineral salts, although volume wise it is not the most important effluent stream.

4.6.1
Effluents Balance

At a molasses distillery producing 120 m^3 of alcohol/24h, the volume of stillage produced (1500 m^3), with a BOD level of about 25 g/liter, amounts to approximately 60% of the pollution load in the total volume of liquid effluents from this type of distillery (Table 13).

Tables 13 to 15 were based on a population equivalent of 54 ppm of BOD/inhabitant-day. Although conservative, this figure has been accepted as representative for Brasilian conditions. The values illustrate that the organic pollution load of a 120 m^3/day

FIGURE 7

EFFECTS OF ENERGY PRODUCTION SYSTEMS BASED ON ACRICULTURAL RESOURCES

ECONOMIC

1- BALANCE OF PAYMENTS
2- EXPORTS
3- SAVING OF ASSETS
4- CREATION OF NEW ECONOMIC FRONTIERS

ENERGETIC

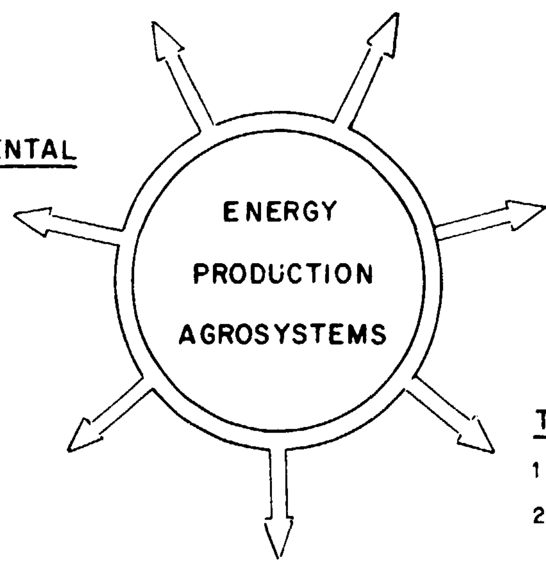
1- EXTERNAL ENERGETICAL INDEPENDENCE
2- ENERGY INTERNALIZATION
3- NEW ENERGY RESOURCES

POLITICAL

1- PARTICIPATION OF NEW POPULATION INTO THE DECISION PROCESSES
2- CHANGES IN THE STILES AND DIRECTION OF THE EXTERNAL RELATIONS FLOWS

ECOLOGICAL-ENVIRONMENTAL

1- UTILIZATION OF RENEWABLE RESOURCES
2- ENVIRONMENTAL EQUILIBRIUM



SPATIAL

1- BETTER UTILIZATION OF THE SPACE
2- INCORPORATION OF NEW AREAS AND RESOURCES
3- INTERNALIZATION OF DEVELOPMENT
4- EXPANSION OF THE INTERNAL ECONOMIC FRONTIERS

SOCIAL

1- CREATION OF JOBS
2- QUALITY AND QUANTITY INPROVEMENT OF LIFE IN THE RURAL AREAS
3- REDUCTION OF REGIONAL INEQUALITIES
4- FIXATION OF THE RURAL POPULATION
5- ELEVATION OF THE INDIVIDUAL INCOME
6- DESACCELERATION OF THE RURAL EXODUS

TECHNOLOGICAL

1- TECHNOLOGICAL INDEPENDENCE
2- DEVELOPMENT OF NEW PROCESSES
3- PROFESSIONAL QUALIFICATION
4- EXPANSION OF THE INDUSTRIAL CAPACITY
5- CREATION AND EXPANSION OF SUPPORTING INDUSTRY

REF. (16)

TABLE 13

LIQUID EFFLUENT BALANCE OF SUGAR FACTORY WITH MOLASSES DISTILLERY

BASIS: 120 m^3 of Absolute Alcohol/24 hours

Stream	Volume (10^3 m^3)	BOD[(a)] (t)	Temperature (^oC)	Population Equivalent (10^3 inhab.)	Population Equivalent (%)
Stillage	1.5	37.5	80	694	63
Sugarcane Wash Water	70	12.3	25-35	233	21
Evaporator Condenser Wastes	150	6.0	40-45	111	10
Floor and Equipment Wash Water	1.2	1.8	25	33	3
Juice Evaporation Condensates	6	0.9	70-80	17	2
Flegmass	0.2	0.2	70	6	1
TOTAL	228.7	58.7	-	1094	100

Note: (a) BOD : Biochemical Oxygen Demand

Ref.: (26; 27; 28; 29; 30; 31; 32; 33).

TABLE 14

LIQUID EFFLUENT BALANCE OF SUGARCANE INDEPENDENT DISTILLERY

BASIS: 120 m^3 of Absolute Alcohol/24 hours

Stream	Volume (10^3 m^3)	BOD (t)	Temperature (^oC)	Population Equivalent (10^3 inhab.)	Population Equivalent (%)
Stillage	1.5	24.6	80	456	85
Sugarcane Wash Water	12.7	2.3	25-35	42	8
Floor and Equipment Wash Water	1.2	1.8	25	33	6
Flegmass	0.2	0.2	70	5	1
TOTAL	15.5	28.8	-	536	100

Note: (a) BOD: Biochemical Oxygen Demand

Ref.: (26; 27; 28; 29; 30; 31; 32; 33).

TABLE 15

LIQUID EFFLUENT BALANCE OF MANDIOCA INDEPENDENT DISTILLERY

BASIS: 120 m^3 of Absolute Alcohol/24 hours

Stream	Volume (10^3 m^3)	BOD[(a)] (t)	Temperature (^oC)	Population Equivalent	
				(10 inhab.)	(%)
Stillage	1.5	28.4	80	525	77
Waste Waters	3.3	5.0	25	92	13
Mandioca Wash Water	2.3	3.4	25 - 30	63	9
Flegmass	0.2	0.2	70	5	1
TOTAL	7.3	37.0	-	685	100

Note: (a) BOD: Biochemical Oxygen Demand

Ref.: (24; 34)

ethanol distillery corresponds to a city of nearly one million inhabitants. The intrinsic differences between the distillery's liquid effluents and domestic sewage should, however, be kept in mind. For instance stillage does not contain any pathogenic microorganisms.

It is therefore of utmost importance to seek solutions that could lead to processes for the recovery of stillage values and at the same time reduce its threat to the environment.

From a volumetric standpoint, however, it should be emphasized that the main polluting stream at the sugar mills are the evaporators and condensers, since they contribute with nearly 150,000 m^3/24 h. Table 16 presents the treatment processes used for water recirculation.

On the other hand, at an independent distillery of the same capacity, stillage accounts for 85% of its total pollution load. In terms of volume, the cane wash waters total 12,700 m^3/day (Table 14). Since all the juice at this type of distillery is directly converted into alcohol, stillage accounts for the larger part of the pollution load.

An independent sugarcane distillery producing 120 m^3 of absolute alcohol/24 h will therefore put out effluents with an organic load equivalent to a city of approximately 540,000 inhabitants. This value represents half the population equivalent of a molasses ethanol distillery of the same capacity. This difference is due to the following:

. About 12% of the pollution load results from cane juice concentration;

. The daily flow of cane to be milled is greater;

. The stillage has a higher solids content.

The effluent balance of an independent mandioca distillery (Table 15) is very similar to that of an independent sugarcane distillery. The population equivalent in this case would be on the order of 690,000 inhabitants.

TABLE 16

TREATMENT PROCESSES FOR WASTE WATER RECIRCULATION IN SUGAR MILL AND DISTILLERIES

Stream	Treatment	Objective
Evaporator Condenser Wastes	. Use of demister in sugarcane juice evaporators	. BOD reduction
	. Spray cooling in open lagoons or use of cooling towers	
Washing water	. Setting	. Removal of sediments
Cooling water	. Cooling towers	. Temperature reduction

4.6.2
Alternatives for stillage products recovery

Processes for reducing the pollution load of liquid effluents generally fall into two categories:

. Degradation processes that reduce the effluent to environmentally inert forms. When effluents contain organic matter, their chemical or biological oxidation will eventually lead to the production of CO_2 and H_2O;

. Recycling processes that convert effluents into marketable products.

Reducing the effluent volume via either degradation or recycling processes will almost always ensure a positive economic benefit. Improvements in ethanol-producing processes that result in lower stillage generation rates are therefore desirable.

The natural depuration capability of water courses may be utilized within certain limitation to decompose stillage into harmless substances. In this case, stillage could be released into the ocean or into rivers, provided that dilution patterns are adequate to inhibit massive localized oxygen depletion.

The high volume of stillage enerated in ethanol manufacture prevents straightforward po. ition abatement for its own sake. Opportunities for economic recycling of stillage values should be pursued although they could render the distillery an unfeasible proposition. Since ethanol compete with gasoline the cost of implementing pollution control technologies, if passed on to alcohol costs may render it economically unfeasible.

Implementation of stillage pollution-abatement should therefore incorporate alternatives for stillage values recovery and recycle in order to ensure a return on the investment, without unduly burdening the cost of alcohol production.

CTP has assessed the technical and economic feasibility of recycling the organic and mineral content of stillage through different products with commercial value. Figure 8 presents main alternatives considered. CTP concluded that, in the Brasilian case, it may be feasible to recover stillage through the following alternatives:

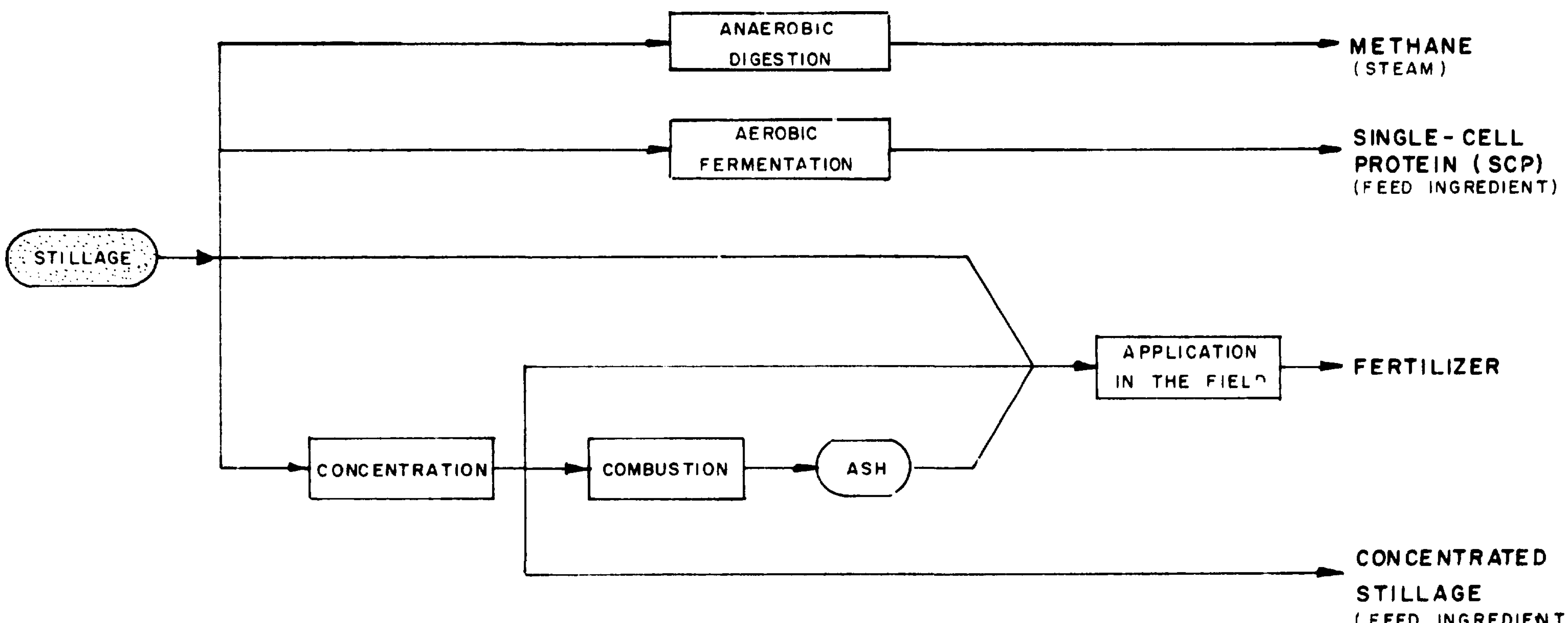
. Spraying in-natura stillage as a fertilizer over the cropland;

. Steam raising by burning methane produced by anaerobic digestion (fermentation) of stillage.

. Commercial production of single-cell protein (SCP) and concentrated stillage for use as a feed ingredient;

FIGURE 8

ALTERNATIVES FOR STILLAGE RECOVERY AND PRODUCTS UTILIZATION



Ref.: (24)

. Commercial production of potassium ashes to be used as fertilizer.

Adoption of one of these alternatives will have a double benefit: improvement of the profitability of stillage-generating alcohol production systems and abatement of pollution problems associated with stillage disposal.

From the process design viewpoint, recycling stillage or converting of into saleable products does not present unsurmountable difficulties. However, careful assessment must be made of economic aspects since ethanol is produced for fuel purposes. This means that the cost of stillage processing must not jeopardize ethanol's competitiveness in the fuelsmarket.

The economic feasibility of these processes depends heavily on specific local conditions such as:

. Scale of production

. Type of stillage

. Market price of substitute conventional products

. Market share of substitute conventional products

. Financing.

The complexity of problems and opportunities associated with stillage recovery and the intrinsic interrelation between these activities and ethanol production suggest the concomitant coupling of the two programs. Large scale production and use of alcohol implies necessarily the commitment of financial and managerial resources to stillage recovery.

4.7 Ethanol as a Substitute of Petroleum Fuels

If one of the objectives of large alternative fuels programs is an actual reduction of the overall petroleum consumption; action has to be taken to substitute not only gasoline, but also diesel oil and fuel oil simultaneously.

Table 17 shows a summary of the performance of ethanol as a substitute of the main petroleum fuels: gasoline, diesel and fuel oil.

"Average volumetric value" accounts for the ratio between the volume of ethanol (anhydrous, hydrated or with additives) and the volume of petroleum fuel (gasoline, diesel or fuel oil) necessary to perform the same task in a given equipment (Otto or Diesel cycle engine, boilers or furnaces). From the point of view of volumetric oil displacement through ethanol utilization the best approach is gasoline-ethanol blends, followed by neat ethanol as gasoline displacer, diesel oil substitution in different ways and fuel oil replacement. This is due to the different heating values of ethanol and petroleum fuels and different efficiencies of the several equipment shown in the table when operating with ethanol or petroleum fuels.

An additional advantage to fuel economy can be detected in TEL (Tetraethyllead) savings due to the fact that ethanol-gasoline blends have a higher octane rating than straight gasoline. Although TEL's impact on final cost of gasoline in Brasil is less than 1%, the yearly savings totalized US$ 16 million in 1978 corresponding to a 50% decrease in TEL consumption. This figure does not take into account environmental benefits reflected by the reduction of lead air pollution (Refs. 24; 35).

However, data presented in Table 17 may not be valid for every country due to differences in petroleum fuels specifications and, consequently, in the vehicles' characteristics. For instance, Brasilian data in the table show a 20% increase of fuel consumption when operating in an Otto engine with neat ethanol, despite the fact that the heating value ratio of gasoline and neat ethanol is 1.6.

In other words, a Brasilian engine operating on neat ethanol shows a higher efficiency (about 30% more) due to the average compression ratio used in Brasil for gasoline engines (about 7:1) whereas the high octane rating of ethanol allows operating at much higher compression ratios (about 10 to 13:1). Regular Otto engines have to undergo minor changes (e.g. change in compression ratio) to fully benefit from neat alcohol fuel.

TABLE 17

PERFORMANCE OF ETHANOL AS A FUEL: SUMMARY

Equipment (Conventional fuel)	Ethanol Utilization	Key points	Lower Heating Value Ratio (Petroleum Fuel/Ethanol)	Volumetric
Otto Engine	. Blends (20% vol. ethanol) 80% vol. gasoline)	- materials compatibility - phase separation - driveability	1.5	1.0
	. Neat ethanol (96°GL)	- engine conversion - cold start - distribution network	1.6	1.2
Diesel Engine (diesel oil)	. Blends (max. 7% vol. ethanol)	- materials compatibility - phase separation		
	. Neat ethanol (plus about 10% cetane improver additive, increase of compression ratio, conversion to Otto cycle or inclusion of "hot point"	- materials compatibility - cost and availability of additives - distribution network	1.7	1.7
	. Dual system (double injection/carburetor and direct injection, emulsifiers, etc.)	- Conversion Cost - Distribution network - Multi-fuel		
Boilers (fuel oil)	. Blends . Neat Ethanol . Dual fuel system	- Materials compatibility - Low competitiveness	1.9	2.0

Ref.: (36)

In addition, the priority of ethanol utilization can vary, depending on how relevant are the aspects of self-sufficiency in oil refining, refining processes flexibility, energy consumption in the ethanol distribution system, and other particular conditions of a given country.

Concerning ethanol utilization in Diesel engines several technologies are being developed in Brasil. In the short run the utilization of cetane improving additives and direct fuel injection may be the best approach. Over the long run, however, ethanol could be displaced by vegetable oils, whose fuel use is currently being developed.

With respect to emissions of pollutants, one can say that utilization of ethanol fuels in Brasil will generally provide a positive benefit, despite the fact that the increase in emissions of certain products, such as aldehydes, may lead to effects not yet very well determined. In general terms CO and unburnt fuel (HC) emissions are reduced as well as NO emissions in most applications.

5. COST OF FERMENTATION ETHANOL PRODUCTION

This Chapter covers the economic parameters prevailing in the Brasilian fermentation ethanol agroindustry. Investment figures of the industrial subsystem are based on CTP estimates and quotations by equipment manufacturers. Agricultural investment and operating costs are expressed in terms of sugarcane, molasses and mandioca prices. Since these prices are administered by the government, it is assumed that it remunerates the farmer adequately.

In ethanol selling price calculation, only ProAlcohol financing (see Appendix A-4) was taken into account. The benefits of economy of scale on selling price can be compared for the three feedstocks considered.

All cost figures reflect the Brasilian economic situation in April, 1980. They were translated in US$ using the exchange rate of Cr$ 50/US$. Table 18 presents the unit cost of the main inputs of fermentation ethanol agrosystem.

5.1 Agricultural Costs

Tables 19 and 20 present the total investment in the agricultural subsystem of sugarcane and mandioca independent distilleries, respectively. Investment in land acquisition accounts for 40 to 50% of the total. The difference between land value in the two cases is due to the fact that mandioca is less demanding than sugarcane in terms of soil fertility. The last has been growing in very good land, sometimes competing with foodcrops.

Working capital participates with 30 to 40% of the total investment. In this case it takes into account the value of planted sugarcane and mandioca roots, including expenses with fertilizers, labor, fuel and other inputs.

Investment in the agricultural sector of a molasses distillery is not assessed since sugarcane costs in molasses production were already computed in the sugar price.

Based on the investment figures shown in Tables 19 and 20, and adopting operating costs practiced in the Center-South regions of Brasil, sugarcane and mandioca roots selling price (CIF distillery, i.e., including transportation) are calculated. Tables 21 and 22 show the breakdown of these selling prices including the benefits of ProAlcohol financing (see Appendix A-4). Some observation can be made from the analysis of these Tables:

. Land is responsible for about 15% of total selling price in both cases;

. Mandioca is labor intensive (36% of selling price) while sugarcane cultivation is mechanized (14% of sugarcane selling price);

TABLE 18

PROCESS INPUTS PRICES

Basis: US$ as of April, 1980

ITEM	UNIT	PRICE (US$/UNIT)
Sugarcane[a]	t	12.34
Mandioca	t	30.60
Sugarcane Molasses[a]	t	53.91
Fusel Oil	t	200
Hydrated Ethanol[a,b]	m^3	300
Wood	t	10.00
Sulphuric Acid	kg	0.13
Superphosphate	kg	0.23
Ammonium Sulphate	kg	0.24
Benzene	kg	0.45
Pentachlorophenol	kg	6.00
Water	m^3	0.02
Electricity	MWh	37.94[c]
Yeast	kg	0.83
Sodium Hydroxide	kg	2.26
Alpha-Amylase	kg	3.3
Glucoamylase	kg	3.4
Diesel Oil	liter	0.25
Urea	kg	0.30
Potassium chloride	kg	0.36

Notes: (a) IAA administered price for the Center-South
(b) 96^{o} GL
(c) Load factor = 0.4

Ref. (37; 38)

TABLE 19

BREAKDOWN OF AGRICULTURAL INVESTMENT IN SUGARCANE INDEPENDENT DISTILLERIES

- Economy of Scale -

ITEM	VALUE (10^3 US$) PER RATED CAPACITY ($m^3$/day)			
	5	30	120	240
LAND[(a)]				
. Acquisition[(b)]	320	1,910	7,640	15,280
. Preparation	30	170	660	1,310
EQUIPMENT[(c)]	50	410	2,380	5,700
AGRICULTURAL INVESTMENT	400	2,490	10,680	22,290
WORKING CAPITAL[(d)]	180	1,060	4,250	8,510
TOTAL AGRICULTURAL INVESTMENT	580	3,550	14,930	30,800

Notes:

(a) 70% of the total required area
(b) Based on land value of 1,200 US$/ha
(c) Equipment for cultivation, harvesting, transportation of sugarcane and stillage
(d) Includes the value of the sugarcane planted (94%) and expenses with personnel corresponding to one year of operation (6%)

(Ref.: 36; 49; 40).

TABLE 20

BREAKDOWN OF AGRICULTURAL INVESTMENT IN MANDIOCA INDEPENDENT DISTILLERIES
- Economy of Scale -
Basis: US$ as of April/80

ITEM	VALUE (10^3 US$) PER RATED CAPACITY ($m^3$/day)			
	5	30	120	240
LAND[a]				
. Acquisition[b]	500	2,970	11,880	23,760
. Preparation	40	260	1,020	2,040
EQUIPMENT[c]	130	1,040	6,040	14,470
AGRICULTURAL INVESTMENT	670	4,270	18,940	40,270
WORKING CAPITAL[d]	410	2,450	9,810	19,630
TOTAL AGRICULTURAL INVESTMENT	1,080	6,720	28,750	59,900

Notes:

(a) Not included land for wood production
(b) Based on a land value of 600 US$/ha
(c) Equipment for cultivation, harvesting and transportation of mandioca roots and stillage
(d) Includes the value of the mandioca roots planted (95 .) and expenses with personnel corresponding to one year of operation

Ref.: (36; 39).

TABLE 21

BREAKDOWN OF SUGARCANE ADMINISTERED SELLING PRICE

Basis: 1 ton of sugarcane

ITEM	UNIT	TECHNICAL PARAMETER	INPUT PRICE (US$/unit.)	VALUE US$/t	VALUE %
Seedlings	t	0.05	12.0	0.60	5
Fertilizers, Pesticides and soil correctives	kg	15.5	0.14	2.33	19
Labor[(a)]	MH/day				
. field works		3.1	0.7	2.17	18
. administrative		0.4	1.6	0.64	5
Machinery[(b)]	h^{-1}	0.18	9.4	1.69	14
Transportation	km				
. inside crop limits		1.2	0.4	0.48	3
. crop-to-distillery		4.0	0.4	1.60	13
Taxes and Insurance	-	-	-	0.10	1
Fixed Capital Cost					
. Land	-	-	-	1.88	15
. Other	-	-	-	0.73	6
Working Capital Cost	-	-	-	0.12	1
TOTAL SELLING PRICE[(c)]	-	-	-	12.34	100

Notes: (a) Includes wages and social charges (56% of wages); MH = Man-Hour
(b) Includes maintenance costs
(c) CIF distillery

Ref.: (41).

TABLE 22

BREAKDOWN OF MANDIOCA ROOTS ADMINISTERED SELLING PRICE

Basis: 1 ton of mandioca roots

ITEM	UNIT	TECHNICAL PARAMETER	INPUT PRICE (US$/unit.)	VALUE	
				US$/t	%
Seedings	m^3	6.0	0.22	1.32	4
Fertilizers, Pesticides and Soil Conditioners	t	1.2	2.78	3.34	11
Labor[(a)]	MH/day				
. Soil preparation		1.3	0.45	0.60	2
. Planting		3.0	0.45	1.35	4
. Weeding and Pesticides Application		15.7	0.45	7.07	23
. Harvesting		4.2	0.45	1.90	6
. Administrative Expenses		1.2	1.30	1.60	5
Machinery	day^{-1}				
. Equipment[(b)]		0.2	5.00	1.10	4
. Animals		4.6	0.32	1.47	5
Transportation[(c)]	km	8.0	0.40	3.20	11
Capital Costs[(d)]	-	-	-	7.15	23
Taxes	-	-	-	0.50	2
TOTAL SELLING PRICE[(e)]	-	-	-	30.60	100

Notes: (a) Includes wages and social charges (56% of wages); MH = Man-Hour
(b) Includes maintenance
(c) Crop-to-distillery root transportation
(d) Mainly land (65% of this value)
(3) CIF distillery

Ref.: (42).

- Sugarcane is more demanding in fertilizers than mandioca;

- Considering the industrial yields for ethanol production from sugarcane and mandioca, 67 liters and 150 liters per ton of feedstock, a unit cost of US$ 0.18 and US$ 0.24 per liter of ethanol results. However, an improvement of about 25% in the agricultural productivity or in the industrial yield of mandioca could equalize these values.

Sugarcane molasses selling price has been administered by the Sugar and Alcohol Brasilian Institute - IAA, since it is a byproduct of the sugar production. The current price (May, 1980) is US$ 53.91 per ton of molasses with 55% of total sugar. An ICM tax of 15% is included in this price (see Appendix A.3).

5.2 Industrial Costs

Industrial costs cover the investment in the industrial sector of agroindustrial systems for fermentation ethanol production from sugarcane and mandioca. The working capital required for the full scale operation of these systems was also included under this item.

Tables 23, 24 and 25 present the total investment for distilleries with rated capacity ranging from 5 to 240 m^3 of absolute ethanol and for the three feedstocks considered. Fixed investment was estimated assuming basic and detailed engineering design services and adoption of modern project management techniques, in order to ensure industrial performance and compliance with 18,24 and 30-month start-up schedules for molasses, sugarcane and mandioca independent distilleries, respectively. Working capital figures were based on material and energy balances shown in Chapter 4 for each type of feedstock and distillery (Table 12).

From the analysis of Tables 23, 24 and 25 it can be concluded that:

- For the same capacity, the total investment in independent distilleries are almost the same, although fixed investment in mandioca distilleries is 25% higher than equivalent sugarcane units. That difference, however, is offset by working capital requirements;

- Working capital figures for sugarcane distilleries double that for mandioca distilleries (alcohol storage period is responsible for this difference - see Tables 26, 27 and 28);

- Due to the fewer number of steps in their production process, which excludes the cost of cane milling and juice treatment, molasses distilleries require a fixed investment roughly 40% lower than independent units. However, total investment climbs to about 55% of that required by independent distilleries, because ethanol storage capacity is 90-day production capacity.

TABLE 23

BREAKDOWN OF INDUSTRIAL INVESTMENT IN SUGARCANE INDEPENDENT DISTILLERIES WITH DIFFERENT RATED CAPACITIES

Basis: US$ as of April, 1980

ITEM	VALUE (10^3 US$) PER RATED DAILY CAPACITY (m^3)			
	5	30	120	240
Field Supervision and General Expenses	90	350	500	600
Land and Site Preparation	10	50	80	100
Technology Licensing Fee	30	80	100	150
Basic Process Design	10	40	80	140
Detailed Engineering and Procurement	70	320	550	690
Equipment and Materials	420	2,180	6,610	11,120
Civil Construction	100	640	1,280	1,810
Erection	80	460	920	1,500
Start-up Expenses	10	10	50	100
Contingencies	80	410	1,000	1,600
Fixed Investment	900	4,540	11,170	17,810
Working Capital	170	1,020	4,070	8,150
TOTAL INVESTMENT	1,070	5,560	15,240	25,960

Ref.: (15; 24; 39; 40; 43)

TABLE 24

BREAKDOWN OF INDUSTRIAL INVESTMENT IN MOLASSES DISTILLERIES WITH DIFFERENT RATED CAPACITIES

Basis: US$ as of April, 1980

ITEM	VALUE (10^3 US$) PER RATED DAILY CAPACITY (m^3)			
	5	30	120	240
Field Supervision, land, site preparation, general and start-up expenses	60	140	230	310
Technology Licensing, Engineering and Procurement	50	180	310	420
Equipment and Materials	180	1,000	2,610	4,240
Civil Construction and Erection	70	350	900	1,480
Contingencies	40	170	400	640
Fixed Investment	400	1,840	4,450	7,090
Working Capital	160	980	3,920	7,840
TOTAL INVESTMENT	560	2,820	8,370	14,930

Ref.: (24; 44; 45).

TABLE 25

BREAKDOWN OF INDUSTRIAL INVESTMENT IN MANDIOCA INDEPENDENT DISTILLERIES WITH DIFFERENT RATED CAPACITIES

Basis: US$ as of April, 1980

I T E M	VALUE (10^3US$) PER RATED DAILY CAPACITY (m^3)			
	5	30	120	240
Field Supervision and General Expenses	100	360	520	720
Land and Site Preparation	20	80	140	230
Technology Licensing Fee	50	70	150	200
Basic Process Design	20	70	120	150
Detailed Engineering and Procurement	150	770	1,280	1,700
Equipment and Materials	450	2,560	7,290	12,140
Civil Construction	130	660	1,460	2,240
Erection	110	640	1,660	2,760
Start-up Expenses	10	60	180	330
Contingencies	100	520	1,270	2,020
Fixed Investment	1,140	5,790	14,070	22,490
Working Capital	80	460	1,850	3,690
TOTAL INVESTMENT	1,220	6,250	15,920	26,180

Ref.: (15; 39)

TABLE 26

SUGARCANE INDEPENDENT DISTILLERY

- STRUCTURE OF WORKING CAPITAL -

Basis: 1 m^3 of absolute ethanol per day

ITEM	UNIT	QUANTITY	US$/UNIT	VALUE (US$)
CURRENT ASSETS				
. Minimum Cash Reserve	-	-	-	825
. Inventories				
Sugarcane	t	15.0	12.34	185
Superphosphate	t	1.4	230	314
Ammonium sulfate	t	1.4	240	324
Sulphuric Acid	t	1.8	130	234
Benzene	kg	58	0.45	27
Pentachlorophenol	kg	25	6	150
Material in Process	m^3	1.7	330	550
Absolute Ethanol	m^3	90	330	29,700
Hydrated Ethanol	m^3	0.4	300	125
Fusel Oil	t	0.2	200	46
Maintenance Materials and Operating Supplies	-	-	-	920
		Subtotal (1)		33,400
CURRENT LIABILITIES				
. Suppliers' Credit				
Superphosphate	t	0.7	230	158
Ammonium sulfate	t	0.7	240	162
Sulphuric Acid	t	0.9	130	116
Benzene	kg	25	0.45	12
Pentachlorophenol	kg	17	6	100
		Subtotal (2)		548
TOTAL	-	-	-	33,948

Ref.: (43; 46)

TABLE 27

MOLASSES DISTILLERY

- STRUCTURE OF WORKING CAPITAL -

Basis: 1 m^3 of absolute ethanol per day

I T E M	UNIT	QUANTITY	US$/UNIT	VALUE (US$)
CURRENT ASSETS				
. Minimum Cash Reserve	-	-	-	390
. Inventories				
Cane Molasses	t	3.33	53.9	180
Superphosphate	t	1.4	230	314
Ammonium Sulfate	t	1.4	240	324
Sulphuric Acid	t	1.8	130	234
Benzene	kg	58	0.45	27
Pentachlorophenol	kg	25	6	150
Material in Process	m^3	0.8	330	264
Absolute Ethanol	m^3	90	330	29,700
Hydrated Ethanol	m^3	0.4	300	125
Fusel Oil	t	0.2	200	46
Maintenance Materials and Operating Supplies	-	-	-	360
		Subtotal (1)		32,114
CURRENT LIABILITIES				
. Suppliers' Credit				
Superphosphate	t	0.7	230	158
Ammonium Sulfate	t	0.7	240	162
Sulphuric Acid	t	0.9	130	116
Benzene	kg	25	0.45	12
Pentachlorophenol	kg	17	6	100
		Subtotal (2)		548
TOTAL	-	-	-	32,662

TABLE 28

MANDIOCA INDEPENDENT DISTILLERY

- STRUCTURE OF WORKING CAPITAL-

Basis: 1 m^3 of absolute ethanol per day

ITEM	UNIT	QUANTITY	US$/UNIT	VALUE (US$)
CURRENT ASSETS				
. Minimum Cash Revenue	-	-	-	1,305
. Inventories				
Fresh Roots	t	3	30.60	92
Enzymes	kg	210	3.3	693
Molasses	kg	270	0.54	145
Yeast	kg	18	0.8	14
Superphosphate	kg	1,022	0.23	235
Ammonium Sulfate	kg	1,015	0.24	244
Pentachlorophenol	kg	20	6.0	120
Sulphuric Acid	kg	5	0.13	1
Sodium Hydroxide	kg	132	2.26	300
Benzene	kg	41	0.45	18
Wood	t	9	10.00	90
Material in Process	m3	1.7	330	550
Absolute Ethanol	m3	30	330	9,900
Hydrated Ethanol	m3	0.4	300	125
Fusel Oil	t	0.2	200	46
Maintenance material and Operating Supplies	-	-	-	414
		Subtotal (1)		14,292
CURRENT LIABILITIES				
. Suppliers' Credit				
Sodium Hydroxide	kg	88	2.26	199
Superphosphate	kg	681	0.23	157
Ammonium Sulfate	kg	677	0.24	162
Sulphuric Acid	kg	3	0.13	0.4
Benzene	kg	27	0.45	12
Pentachlorophenol	kg	13	6.0	78
Yeast	kg	1.2	0.8	1
Molasses	kg	18	0.54	10
Enzymes	kg	140	3.3	463
		Subtotal (2)		1,082
TOTAL	-	-	-	15,378

Ref.: (15)

. In all cases, equipment and materials account for more than 50% of the fixed investment, indicating that any simplification or improvement in equipment will reduce significantly total investment.

Based on the material and energy balances for each type of distillery, operating costs were estimated as it can be seen in Tables 29, 30 and 31. Raw material cost is the major cost item in all cases, accounting for 80, 90 and 70% of total cost in sugarcane, molasses and mandioca distilleries respectively. In the last, wood and electricity participate with 12% of total cost since mandioca requires external sources of fuel and imported enzymes contribute with 5% of the total.

Table 32 shows the FOB - distillery selling prices calculated for ethanol produced at independent and molasses distilleries, computed to yield the investor a 15% annual ROI figured according to the discounted cash flow (DCF) method. Calculation of those prices was based on ProAlcohol financing (Appendix A.4). Average annual inflation over the period was assessed at 40%. The calculated price therefore reflects the benefit of economy of scale and that of subsidized financing at interest rates below the rate of inflation.

Over the range of capacities considered (5 to 240 m^3 of ethanol/day) a 15% annual ROI is sufficient to remunerate the investor keeping the selling price of ethanol below the administered market price of absolute fuel alcohol of US$ 330/m^3. These values therefore indicate that alcohol produced at independent and molasses distilleries is commercially competitive at the producer level.

It is evident that molasses distilleries present the highest margin of profit when ethanol is sold at its official market price, since the infrastructure required for the normal operation of such distillery is already available at the sugar mill.

The simultaneous analysis of Tables 29, 30, 31 and 32 points out the salient position that feedstock costs occupy in the make-up of the price of fermentation ethanol. Figures ranging from 55 up to 70% indicate this heavy dependence on feedstock cost. Consequently, fluctuations in sugarcane, molasses and mandioca prices can jeopardize the competitiveness of ethanol against conventional fuels. On the other hand, however, benefits to be obtained from increased agricultural yield and consequent lower feedstock costs are evident.

TABLE 29

SUGARCANE INDEPENDENT DISTILLERY
- PROCESS INPUTS CONSUMPTION AND PRICE -

Basis: . 1 m^3 of absolute ethanol per day
. US$ as of April, 1980

ITEM	UNIT	CONSUMPTION (UNIT / DAY)	PRICE (US$/UNIT)	VALUE (US$/DAY)	VALUE % OF TOTAL COST
VARIABLE COSTS					
Sugarcane	t	15.0	12.34	185	80
Superphosphate	kg	22.7	0.23	5	2
Ammonium Sulfate	kg	22.5	0.24	5	2
Sulphuric Acid	kg	30.0	0.13	4	2
Benzene	kg	0.9	0.45	0.4	-
Pentachlorophenol	kg	0.44	6.00	3	1
Water	m^3	18.3	0.02	0.4	-
Stillage Treatment	m^3	13.0	0.18	3	1
			Subtotal (1)	206	88
BY-PRODUCTS CREDIT					
Hydrated Ethanol	liter	42	0.30	(13)	(6)
Fusel Oil	kg	4	0.20	(1)	-
			Subtotal (2)	(14)	(6)
FIXED COSTS					
Labor	-	-	-	15	6
Administrative Expenses	-	-	-	7	3
Maintenance	-	-	-	15	6
Insurance	-	-	-	6	3
			Subtotal (3)	43	18
TOTAL	-	-	-	235	100

Ref.: (38; 43; 46)

TABLE 30

MOLASSES DISTILLERY

- PROCESS INPUTS CONSUMPTION AND PRICE -

Basis: . 1 m^3 of absolute ethanol per day
. US$ as of April, 1980

ITEM	UNIT	CONSUMPTION (UNIT / DAY)	PRICE (US$/UNIT)	VALUE (US$/DAY)	VALUE % OF TOTAL COST
VARIABLE COSTS					
Cane Molasses	t	3.33	53.9	180	89
Superphosphate	kg	22.7	0.23	5	3
Ammonium Sulfate	kg	22.85	0.24	5	3
Pentachlorophenol	kg	0.4	6.0	2	1
Sulfuric Acid	kg	30	0.13	4	2
Benzene	kg	0.9	0.45	0.4	-
Water	m^3	16.2	0.02	0.3	-
Stillage Treatment	m^3	13	0.18	3	1
		Subtotal (1)		200	99
BY-PRODUCTS CREDIT					
Hydrated Ethanol	liter	52	0.3	(16)	(8)
Fusel Oil	kg	5	0.2	(1)	-
		Subtotal (2)		(17)	(8)
FIXED COSTS					
Labor	-	-	-	8	4
Administrative Expenses	-	-	-	3	1
Maintenance	-	-	-	6	3
Insurance	-	-	-	2	1
		Subtotal (3)		19	9
TOTAL				202	100

Ref.: (38; 43)

TABLE 31

MANDIOCA INDEPENDENT DISTILLERY

- PROCESS INPUTS CONSUMPTION AND PRICE -

Basis: . m^3 of absolute ethanol per day
. US$ as of April, 1980

ITEM	UNIT	CONSUMPTION (UNIT / DAY)	PRICE (US$/UNIT)	VALUE (US$/DAY)	VALUE % OF TOTAL COSTS
VARIABLE COSTS					
Fresh Roots	t	6.67	30.6	204	68
Alpha amylase	kg	1.26	3.3	4	1
Glucoamylase	kg	3.42	3.4	12	4
Molasses	kg	6.0	0.54	3	1
Yeast	kg	0.40	0.8	0.3	-
Superphosphate	kg	22.70	0.23	5	2
Ammonium Sulphate	kg	22.55	0.24	5	2
Pentachlorophenol	kg	0.44	6.0	3	1
Sulphuric Acid	kg	0.10	0.13	0.01	-
Sodium Hydroxide	kg	2.93	2.26	7	2
Benzene	kg	0.90	0.45	0.4	-
Wood	t	1.70	10.00	17	6
Electricity	kWh	448	0.04	18	6
Water	m^3	31.5	0.02	1	-
Stillage Treatment	m^3	13	0.18	2	1
			Subtotal (1)	282	94
BY-PRODUCTS CREDIT					
Hydrated Ethanol	liter	52	0.30	(16)	(5)
Fusel Oil	kg	4.8	0.20	(1)	-
			Subtotal (2)	(17)	(5)
FIXED COSTS					
Labor	-	-	-	16	5
Administrative Expenses	-	-	-	6	2
Maintenance	-	-	-	9	3
Insurance	-	-	-	4	1
			Subtotal (3)	35	11
TOTAL				300	100

Ref.: (15; 38; 43)

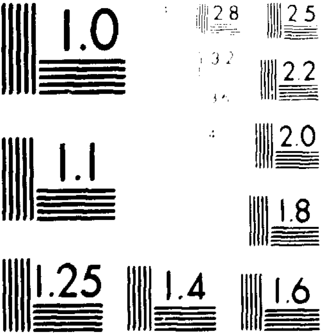
TABLE 32

ECONOMY OF SCALE OF CALCULATED ETHANOL SELLING PRICE

Basis: . ProAlcohol Financing
. 15% p.a. ROI rate

RATED DAILY CAPACITY (m^3)	SELLING PRICE (US\$/m^3) PER TYPE OF DISTILLERY		
	MOLASSES	INDEPENDENT	
		SUGARCANE	MANDIOCA
5	280	325	350
30	276	313	332
120	273	303	320
240	268	285	312

Note: Administered Selling Price of Absolute Ethanol is US\$ 330/m^3 (May, 1980)


1.0
2.8
2.5
3.2
2.2
2.0
1.1
1.8
1.25
1.4
1.6

6.
COST MODEL

6.1
Methodology

The cost model developed by CTP covers the financial analysis of fermentation ethanol producing system using different feedstocks and allows for the influence of specific country economic conditions.

As a function of ethanol distillery output, the model can calculate the ethanol selling price for different distillery concepts.

The model keeps generality although the example calculations are based on technical and economic parameters prevailing in Brasil.

Figure 9 depicts in a block diagram the methodology embodied in the model.

As said before, social cost/benefits analysis (referred to in the text as economic analysis) could be performed through the use of the model provided shadow prices and opportunity costs are available for the specific case under study.

6.2
General Premises

6.2.1
Operating Periods of the System

Sugarcane fermentation ethanol is produced only during part of the year in Brasil, coupled with sugarcane harvest. This fact, which leads to a seasonal alcohol supply, substantially affects the profitability of sugarcane based distilleries in Brasil.

Some by-product distilleries stock molasses during the harvest period for between-harvest alcohol production. Thus ethanol will be produced over a longer period, therefore increasing utilization of the facilities and consequently benefiting project profitability. This situation can also be verified for distilleries operating on imported molasses.

On the other hand, any manner of prolonging the sugarcane harvest period would be equally beneficial. This might be attained through selection of suitable cane varieties and improvement of growing practices such as use of irrigation.

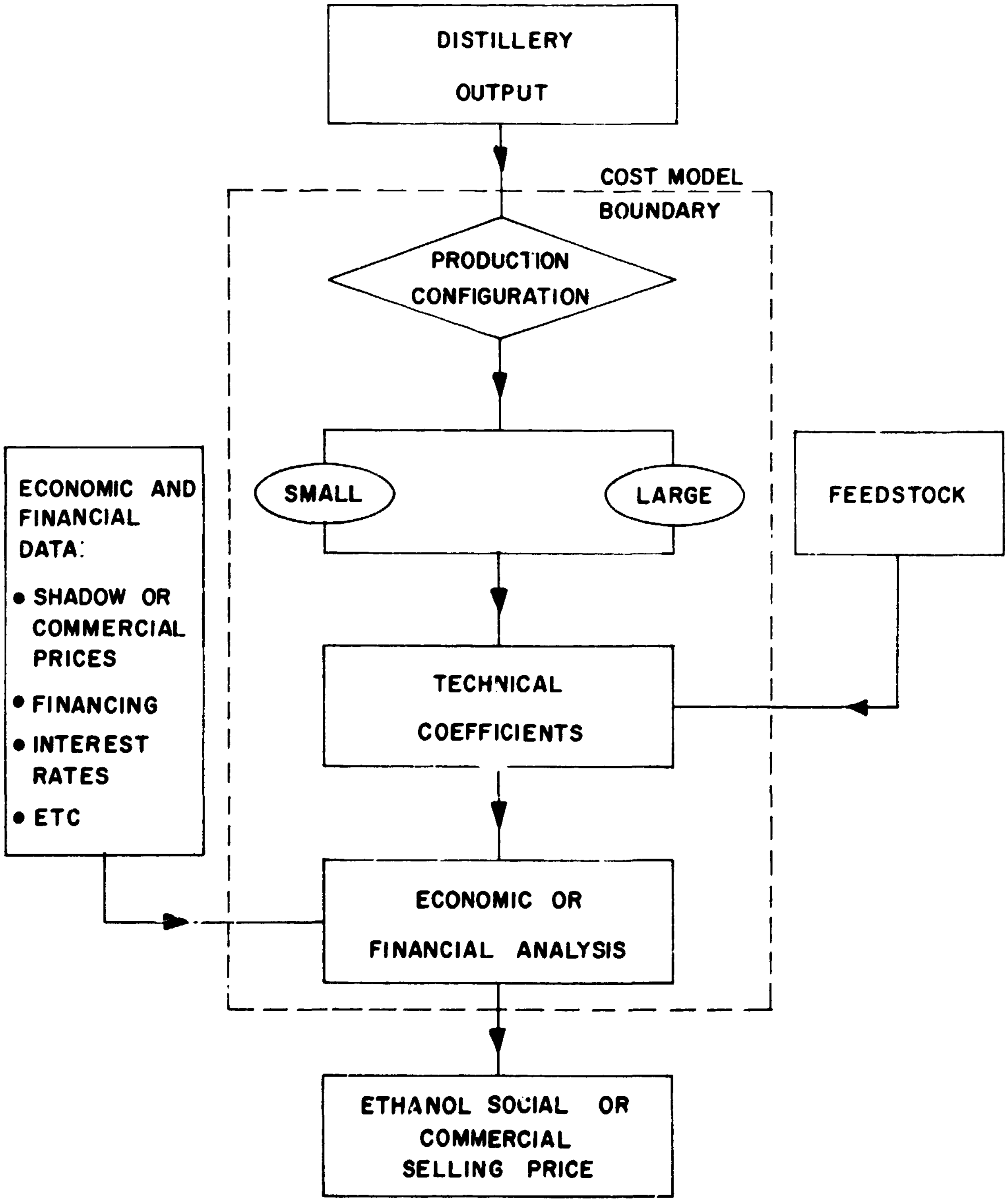
Alternatively supplying the distillery during sugarcane off season with feedstocks other than sugarcane, such as sweet sorghum, could extend utilization of the distillery.

The operating periods of Brasilian distilleries are presented in Tables of chapter 4, page 35.

FIGURE 9

FINANCIAL COST MODEL

-BLOCK DIAGRAM-



It is clear that the longer operating period of independent mandioca distilleries - a consequence of the longer harvest period - results in better use of installed capacity and thus higher unit operating rates.

6.2.2 Range of Capacities

The study covers the range of daily capacities from 5 to 240 cubic meters of absolute ethanol. The energy and material balances for 1 m^3 of ethanol presented in chapter 4 (Table 12), are valid within 30% variation for this range of rated capacities.

Fixed investment of the distillery is subject to economy of scale. The exponential coefficient, k, varies from 0.6 to 0.7 for the range of capacities and alternative feedstocks considered.

6.2.3 Battery Limits

Ethanol distilleries have been assessed within their respective battery limits, which comprised the industrial processing unit itself, the agricultural system, the system for transportation of feedstock and distribution of stillage as fertilizer.

By-product distilleries were supposed to operate integrated with sugar mills, a condition which will be prevalent in traditional sugar producing countries. However, there would be commercial and/or strategical reasons for implementing byproduct distilleries based in imported molasses, as the case of Europe.

Drawings No. CT-UN01-004 and 005 present the model boundaries for independent and molasses distilleries, respectively.

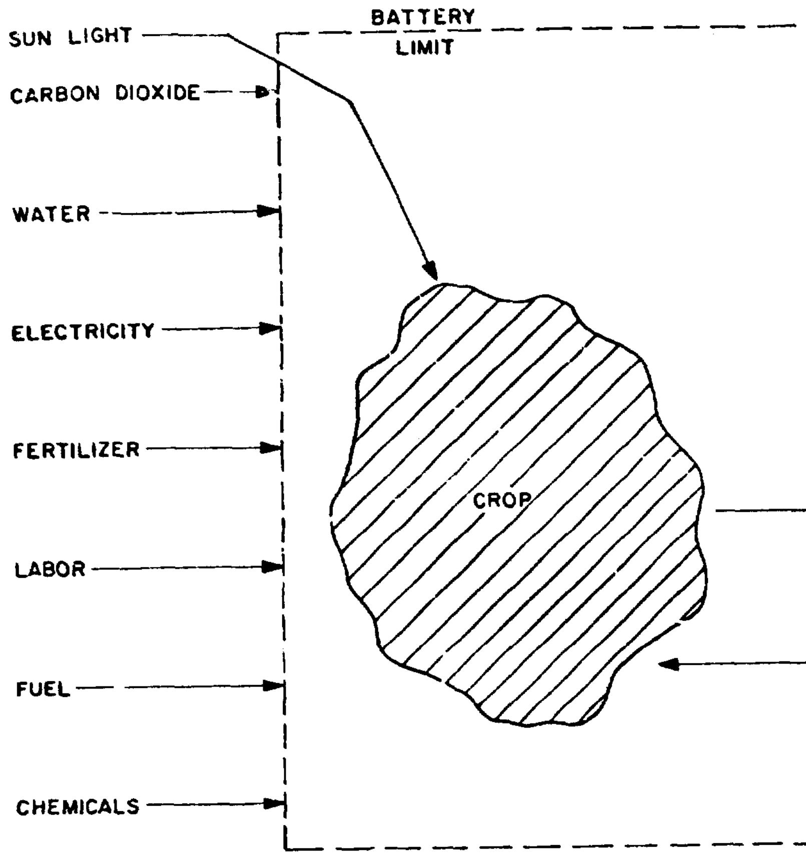
Feedstock costs correspond to hypothetical input transfer prices on which taxes are not computed. This would be effective if the plantation and distillery facilities are under different ownership. The same situation applies for utilities cost, delivered from sugar mills to molasses distilleries.

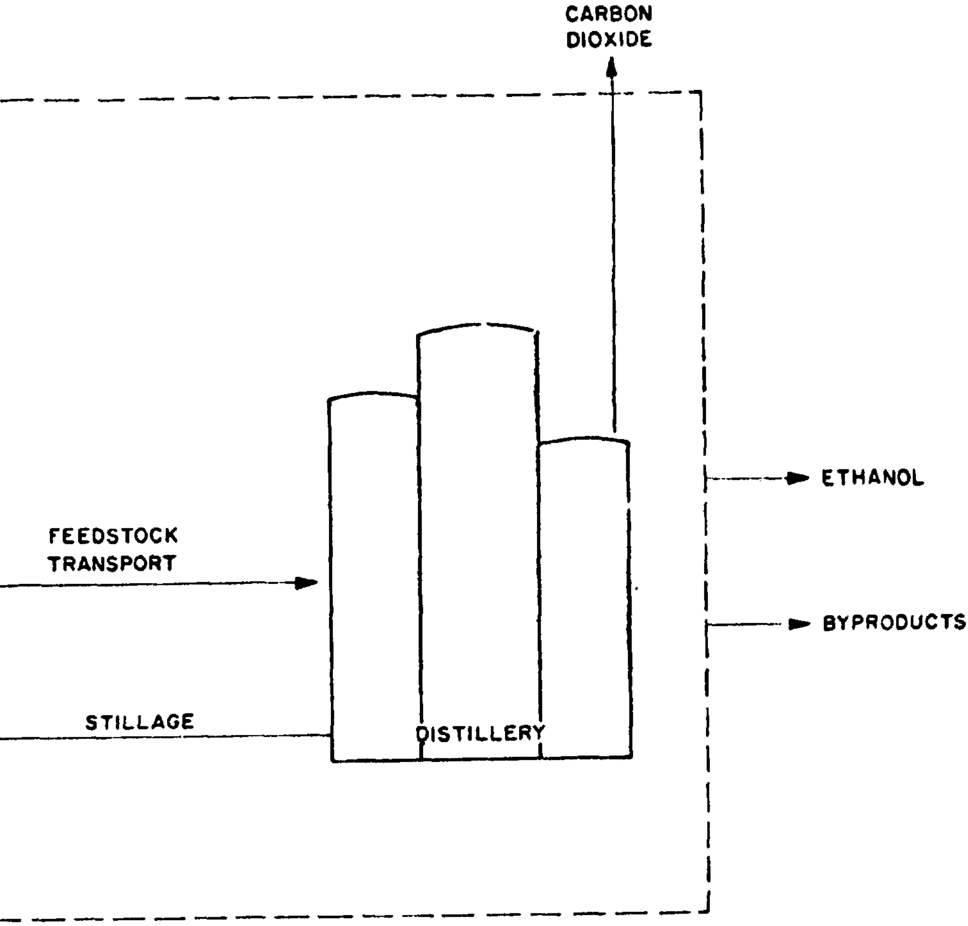
6.2.4 Source of Financing

In the financial analysis, the sources of funds necessary for project implementation were the following:

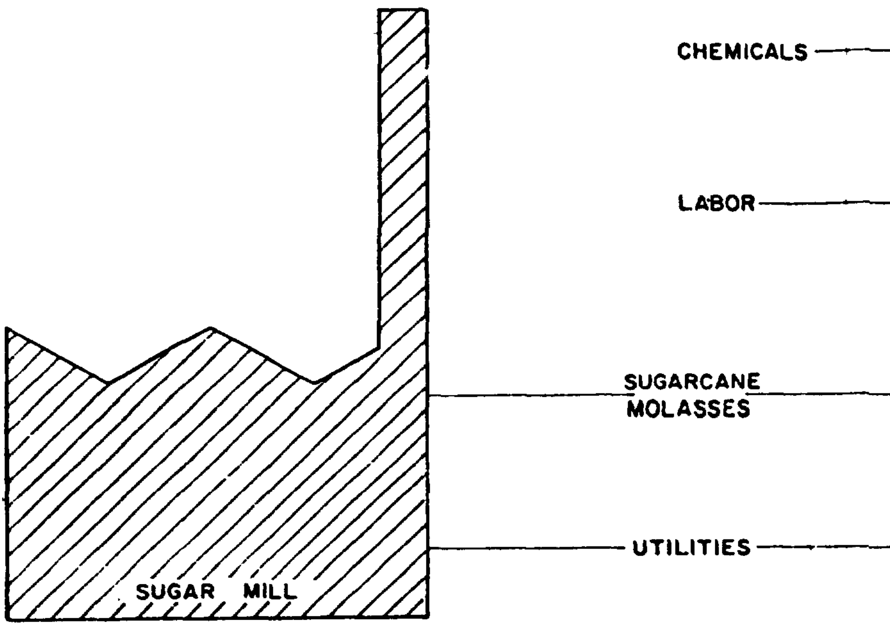
. investor's own resources

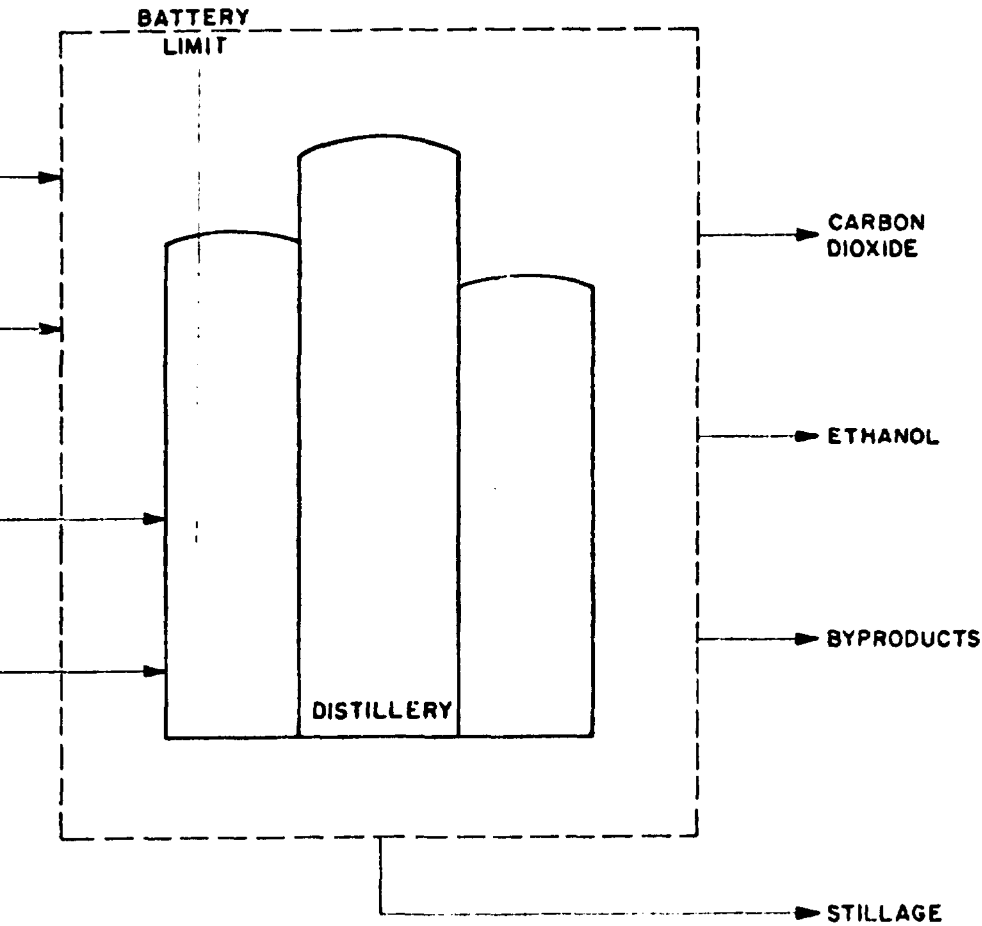
. financing at commercial rates


BATTERY LIMIT
SUN LIGHT
CARBON DIOXIDE
WATER
ELECTRICITY
FERTILIZER
LABOR
FUEL
CHEMICALS
CROP



PROJECT: FERMENTATION ETHANOL PRODUCTION COST MODEL				
TITLE: INDEPENDENT DISTILLERY MODEL				
REV.	DWN:	DATE:	CHK:	NO. CT-UN01-004
0	CB/PC	05.05.80	CB	


CHEMICALS
LABOR
SUGARCANE MOLASSES
UTILITIES
SUGAR MILL



PROJECT: FERMENTATION ETHANOL PRODUCTION COST MODEL				
TITLE: SUGARCANE MOLASSES DISTILLERY MODEL				
REV.	DWN:	DATE:	CHK:	NO.
0	CB/PC	05.05.80	CB	CT-UN01-005

The model is able to evaluate the impact of different financing on transfer costs and selling prices. In order to measure the benefits of subsidized financing, the model takes into account inflation, monetary correction and differential cost increase of inputs and services during the period of financial analysis.

Agricultural and industrial financing currently prevailing in Brasil are described in detail in Appendix A-4.

6.2.5 Implementation and Disbursement Schedules

Appropriate management practices should be applied to prevent failures and delays, during the different phases of the implementation of fermentation alcohol projects.

Modern management practices are common in the implementation of chemical, petrochemical, mining and large scale civil work projects.

Fuel alcohol production projects will increasingly approximate the above mentioned list. The adoption of modern management routines are hence mandatory.

The interaction between agricultural and industrial implementation activities for a sugarcane distillery is shown in the bar chart of Figure 10. There should be a perfect linkage of the activities in such a way that the distillery start-up coincides with the first cane harvest. A del could lead to the loss of the entire harvest.

Technical evaluation of the industrial part of the agroindustrial system for ethanol production and the accumulated experience in project implementation led to the typical progress curves shown in Figure 11. These were defined for the major implementation activities from both physical progress and cash outflow standpoints:

. Process engineering, basic and detailed design

. Equipment and materials procurement

. Civil works (foundations and buildings)

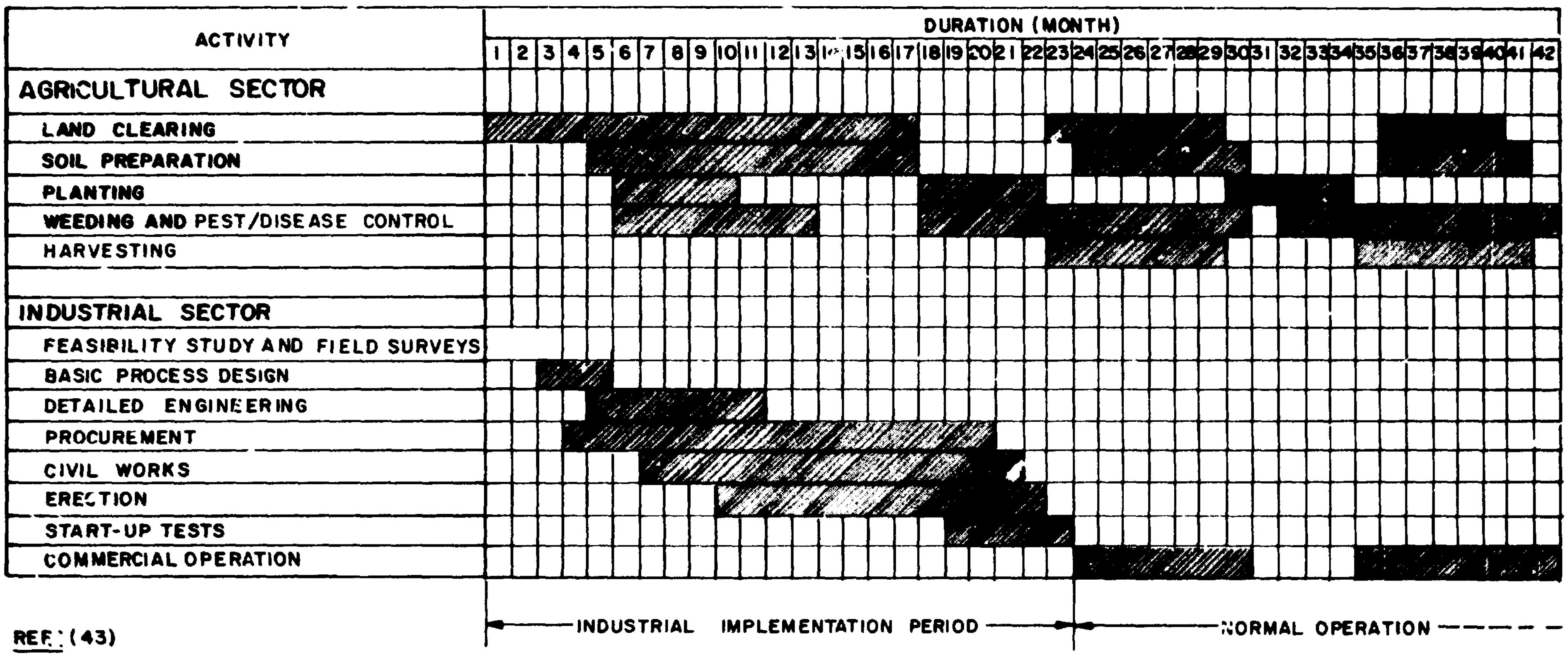
. Electrical and mechanical assembling including installation of equipment, piping and fittings, instrumentation, electrical insulation and painting.

The curves, shown in Figure 11 for distilleries with daily capacity over 30 m^3 of ethanol, made it possible to prepare disbursement schedules for technical assets, financial charges and working capital. This schedule was established as follows:

SUGARCANE AGROINDUSTRIAL SYSTEM FOR ETHANOL PRODUCTION

- TYPICAL INTEGRATED IMPLEMENTATION SCHEDULE -

BASIS: 120 m^3 OF ABSOLUTE ETHANOL PER DAY

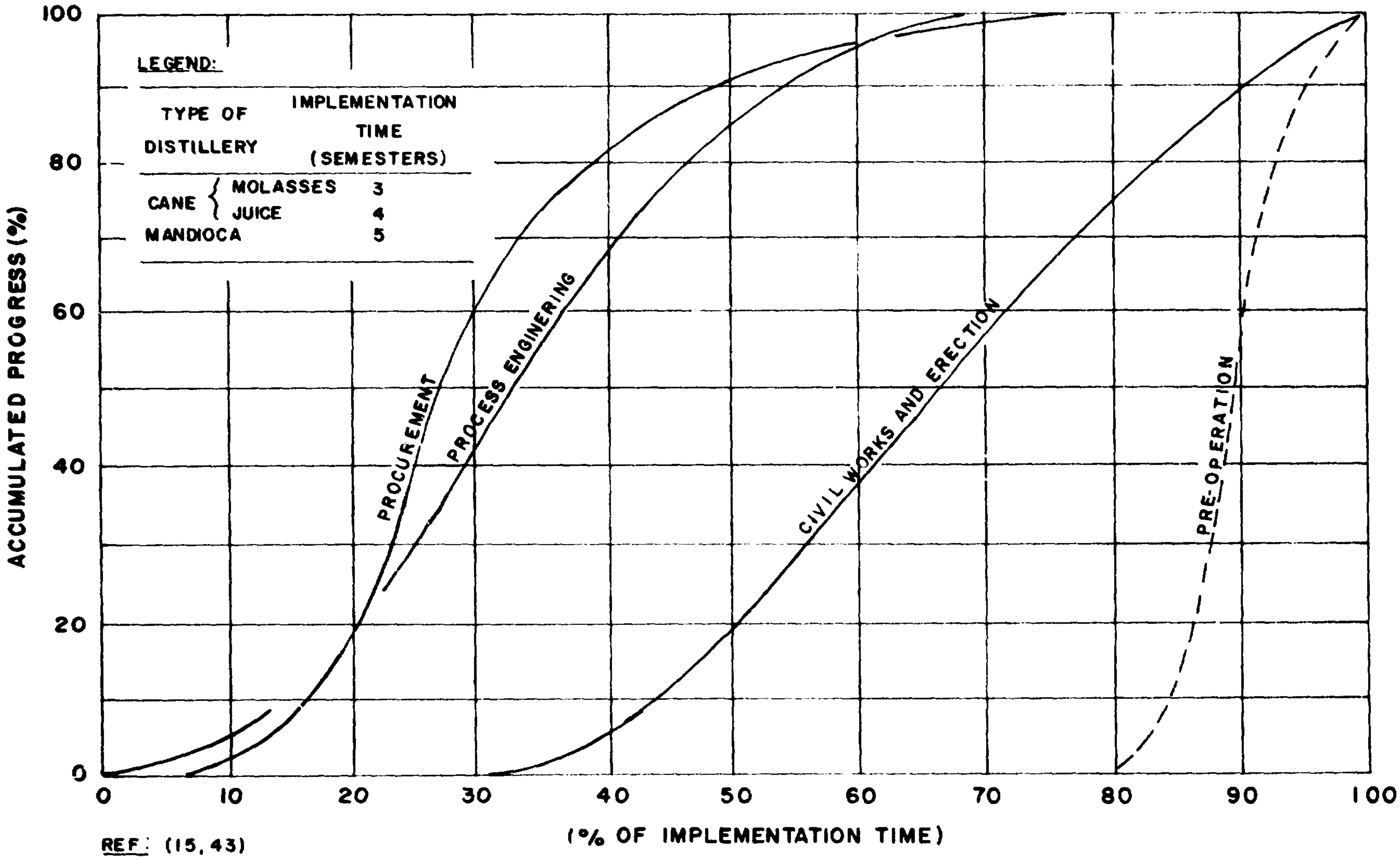


REF.: (43)

FIGURE 11

ETHANOL DISTILLERY IMPLEMENTATION SCHEDULE

- TYPICAL PROGRESS CURVES -



REF: (15, 43)

. Technical assets: cash outflows calculated by summing up disbursements for each activity/event, allocated at six-month intervals according to the proper curves.

. Financial charges and costs: interests, charges, fees and commissions, calculated for six-month periods, for each financial scheme.

. Working capital: a single cash outflow, at the end of the implementation period.

Cash flow assumed that funds for technical assets will be available at the beginning of the semester during which they will be used: for financial costs and charges, at the beginning of the semester in which they are due; and working capital, at the conclusion of implementation.

6.3
Fixed Investment

Capital requirements, encompassing fixed investment in technical assets, financial costs and working capital, have to be estimated for each type of distillery.

The calculation of each component of technical assets was based on the distillery concepts showed in the previous chapters. The main components of the fixed investment are listed below:

TECHNICAL ASSETS

. General and Administrative Expenses
  - Surveys and studies
  - Legal and administrative expenses

. Project Management

. Land and Site Preparation
  - Agricultural sector
  - Industrial sector

. Technology Licensing

. Engineering and Procurement
  - Basic process design
  - Detailed engineering
  - Procurement

. Equipment and Materials
  - Equipment
  - Piping and fittings
  - Instrumentation
  - Electrical materials
  - Insulation and painting

. Civil Works

. Erection

. Pre-operation and Start-up Expenses

- Training of personnel

- Pre-operation and start-up

FINANCIAL COSTS

. Financial charges, fees and interest during implementation period.

The investment items should be evaluated for a specific country/region at local equipment manufacturer's or by comparison with projects already implemented. The figures presented in chapter 5 correspond to Brasilian conditions and should be used only as a reference for other countries.

Financial charges and costs were calculated on a case by case basis for each particular type of distillery and for each mode of financing.

6.4 Working Capital

The working capital required for plant start-up and operation at full capacity was estimated for each type of distillery and assumed as provided from the entrepreneur's own resources.

The bases adopted in calculating working capital are shown in Table 33 for sugarcane and mandioca distilleries.

Minimum cash reserve is a monthly provision for expenses with electricity, wages, social security and worker's benefits, insurance, taxes and other general expenses.

Current liabilities correspond to a 30-day supplier's credits for the following items: chemicals, maintenance and operating supplies and utilities (electricity).

Inventories refer to the minimum amount of a specific item to be stored in the distillery to assure a continuous ethanol production. The feedstock inventories are based on a constant external supply of sugarcane and mandioca roots whatever the case. In the case of sugarcane molasses this assumption will be also valid provided the distillery is attached to the sugar mill.

The absolute ethanol inventory depends directly on the length of the harvest period. For mandioca distilleries this is relatively small due to the longer operation over the year. In contrast, sugarcane distilleries have to keep a much larger alcohol inventory to assure supply during off harvest season.

TABLE 33
FERMENTATION ETHANOL PRODUCTION
- BASES FOR CALCULATING WORKING CAPITAL -

ITEM	CORRESPONDING PERIOD	VALUE	
		SUGARCANE DISTILLERY	MANDIOCA DISTILLERY
CURRENT ASSETS			
. Minimum Cash Reserve	day	30	30
. Inventory			
- Feedstock	hour	24	10
- Chemicals	day	60	45
- Wood	day	-	5
- Fertilizers[(a)]	day	45	30
- Processing products	hour	40	40
- Absolute ethanol	day	90	30
- Hydrated ethanol	day	10	10
- Fusel oil	day	60	60
- Maintenance materials and operating supplies	day	60	45
CURRENT LIABILITIES			
. Suppliers' Credit	day	30	30

Note: (a) Not applicable for molasses distilleries.

Ref.: (15)

The following expression applies to the calculation of ethanol inventory as a function of the operation period.

$$E_I = P. (1 - t/365)$$

where

E_I is the ethanol inventory, in m^3

P is the annual ethanol production, in m^3

t is the operating period, in days.

6.5 Operating Costs

All costs and expenses which contribute to the selling price of ethanol are based on the following items:

. Annual production: the total distillery production at 100% of installed capacity for one operating period.

. Variable costs: taken as the cost of chemical inputs, process auxiliary products and utilities deducted from the value associated with utilities and byproducts produced by the distillery. These cost calculations were based on process unit consumptions developed in material and energy balances of each type of distillery. Prices were obtained from suppliers.

. Fixed costs: include labor, maintenance, materials and operating supplies, insurance, general overhead and administrative expenses of distillery, calculated on an annual basis. Personnel expenses were calculated from direct and indirect labor required to manage and operate each type of distillery including social security and workers benefits levied on wages and salaries. A flat 20% was added to the total to cover general distillery overhead and administrative expenses.

. Maintenance costs include materials, spare parts and labor and was assumed to be equivalent to a percentage of the total investment for the distillery.

Annual insurance cost also corresponds to a percentage of the fixed investment in the distillery.

. Depreciation: includes depreciation of technical assets and amortization of loans, computed annually in accordance with the tax laws. The depreciation/amortization rate is usually considered equal for the total investment for a 10 year period.

. Taxes: include taxes such as the Brasilian ICM, IPI and PIS where applicable. A special chapter in Appendix A is dedicated to tax calculations and definition.

6.6 Economic and Financial Analysis

Agroindustrial systems for ethanol production were evaluated through an analysis of their economic or financial performance for a given set of economic and financial conditions.

This performance is expressed in terms of a selling price calculated in such a way to ensure satisfactory return on the entrepreneur's capital invested in the distillery, at predetermined recovery rates. Economic or financial feasibility was assessed through the discounted cash flow method (DCF) used to determine selling prices.

Each type of distillery is assessed from the start of implementation to the end of its operating life-span, set usually at fifteen years. The basic premise for this evaluation is that the selling price of the product allows a sufficient margin of profit for capital recovery at a predetermined interest rate. This profit or investor's annua capital recovery over the distillery's operating life-span covers annual cash flows obtained by deducting the following costs from the gross annual revenues:

. Fixed and variable costs, the sum of which is called the industrial costs;

. Taxes levied on the product at sale (i.e. Brasil's ICM, IPI and PIS);

. Amortization, interest and financial charges;

. Income tax on gross annual profit (i.e. tax on the difference between revenue and total operating costs or the sum of industrial costs, depreciation and taxes, plus interest and financial charges).

It should be noted that the provisions for depreciation remains in cash balance, inasmuch as it does not constitute a disbursement. The value of depreciation is ascertained only for the purpose of calculating income taxes.

A cash inflow was credited in the last operating year corresponding to the plant salvage value equivalent to a percentage of the technical assets plus the amount corresponding to demobilization of working capital.

By definition, the project internal rate of return calculated by the DCF method is the interest rate whereby present worth of net cash inflows from the operation (including the salvage value and demobilization of working capital) equals the sum of the present worth of cash outflows in the investor's own-capital investment made during project implemertation. Figure 12 illustrates the cash flow over the life-span of a specific project based on the described model.

The foregoing methodology does not permit a measurement of the benefits of subsidized financing or its effect on the selling price of alcohol since all values are taken at constant prices without allowance for inflation.

For calculation purposes, the rate of inflation will be treated as a rate of interest. The values of two prices at different periods of time would be equal if one considers that the inflation rate only corrects the monetary value of the amount in order to maintain its purchasing power constant.

Monetary values at different periods of time, expressed as current values in their respective time frames, can be compared in terms of purchasing power only if translated into constant values for a single reference period. In the model, the beginning of project implementation was taken as the reference date.

Project economic/financial analysis is customarily carried out in constant values taken on the date of evaluation, assuming that inflation each year will uniformily affect all cash inflows and outflows. Some items can be differentially readjusted depending on their price behavior or the specific conditions prevailing in the country/region.

The equations used in the cost model development are described in detail in Appendix B. Drawing No. CT-UN01-006 illustrates the sequence of calculation adopted in the cost model.

6.7 Model Capabilities

The cost model developed herein can be programmed in desk calculators, such as HP-67, TI-59 or equivalent.

The error associated with estimating selling price of alcohol using the cost model is dictated by the accuracy of process inputs and utilities costs as well as the error taken in fixed investment calculation.

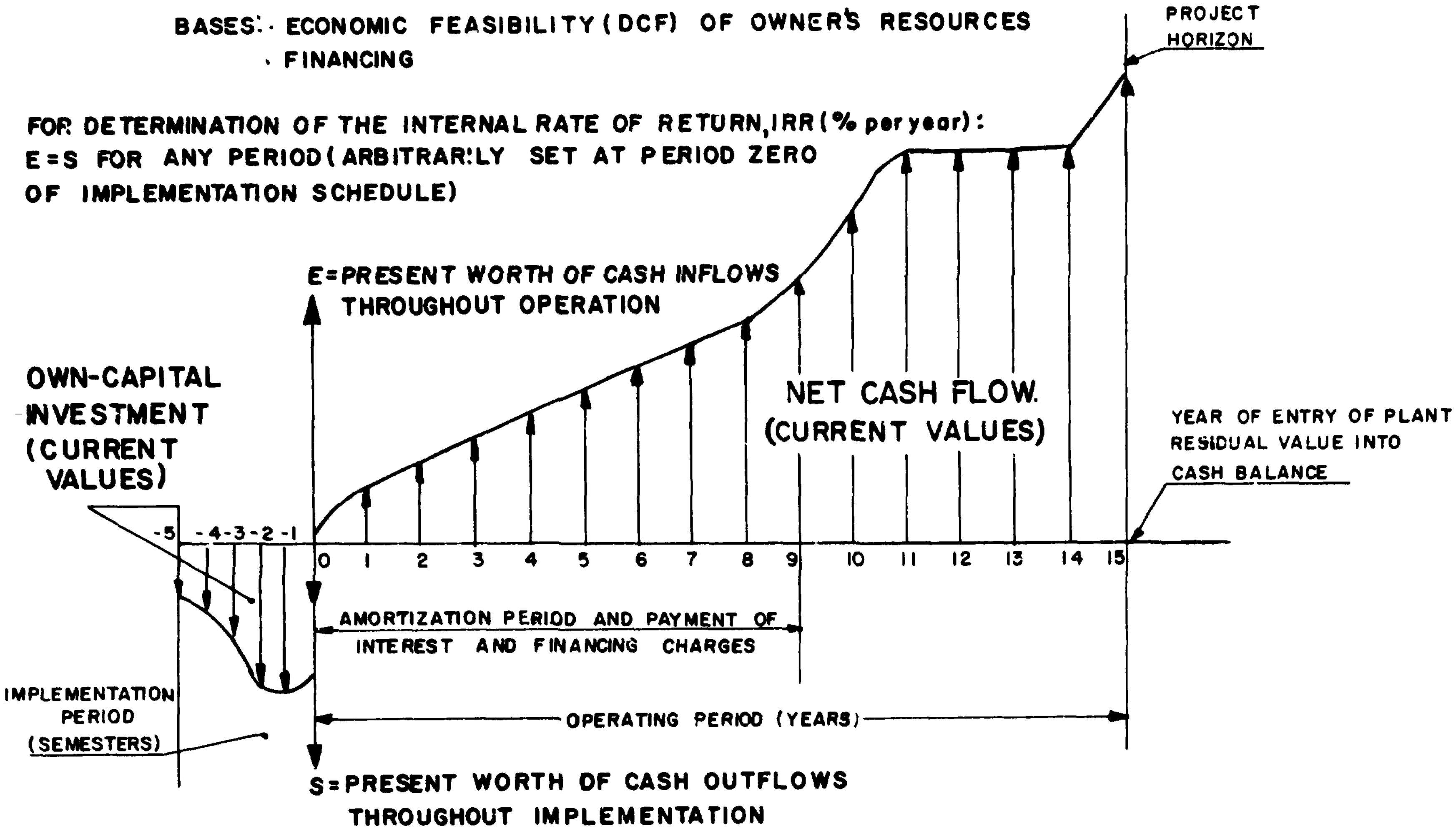
As said before, the model was developed in a general form to allow economic or financial analysis of agroindustrial ethanol production at specific country conditions.

The cost model developed by CTP is able to perform sensitivity analysis of ethanol selling price to various parameters, such as:

. Financial schemes
. Rate of return
. Economy of scale
. Raw material and process inputs costs

FIGURE 12

ECONOMIC EVALUATION OF FERMENTATION ETHANOL PRODUCING SYSTEMS
CASH FLOW SCHEMATICS



. Subsidies
. Inflation rate
. Technology

6.8 Example

A selected sugar cane independant destillery with an ethanol daily output of 120 m^3 as an example of model utilization. The calculation was based on data reflecting the current situation in Brasil's South-Central region. All costs values are referred to April 1980, and were translated into US$ currency at the official rate of Cr$ 50/US$1.

The capital required to implement the industrial part of the project comes from investor's own resources and totals US$ 11,2 million. Table 34 shows the breakdown of this fixed investment. The disbursement schedule during implementation is present in Table 35, following the curve shown in Figure 13.

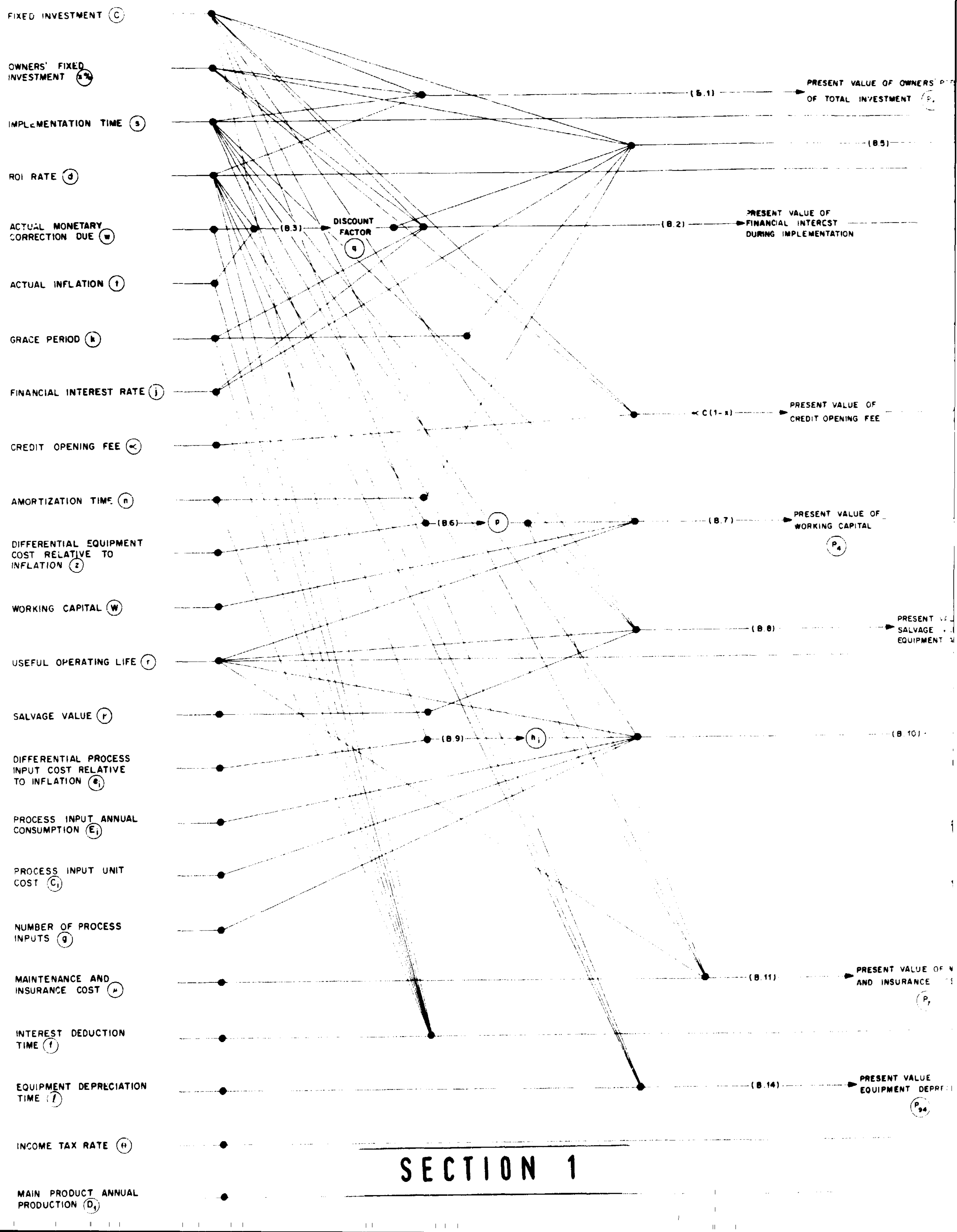
Working capital for the distillery operation, including ethanol storage equivalent to a period of 90 days, amounts US$ 4 million and is provided by the investor. Ethanol inventory accounts for about 90% of this total (Table 36).

The operating costs were estimated taking into account the material and energy balances shown in chapter 4 and Brasilian market prices for each process input. Table 37 depicts consumption and prices for distillery inputs, at a rated daily capacity of 120 m^3 of absolute ethanol.

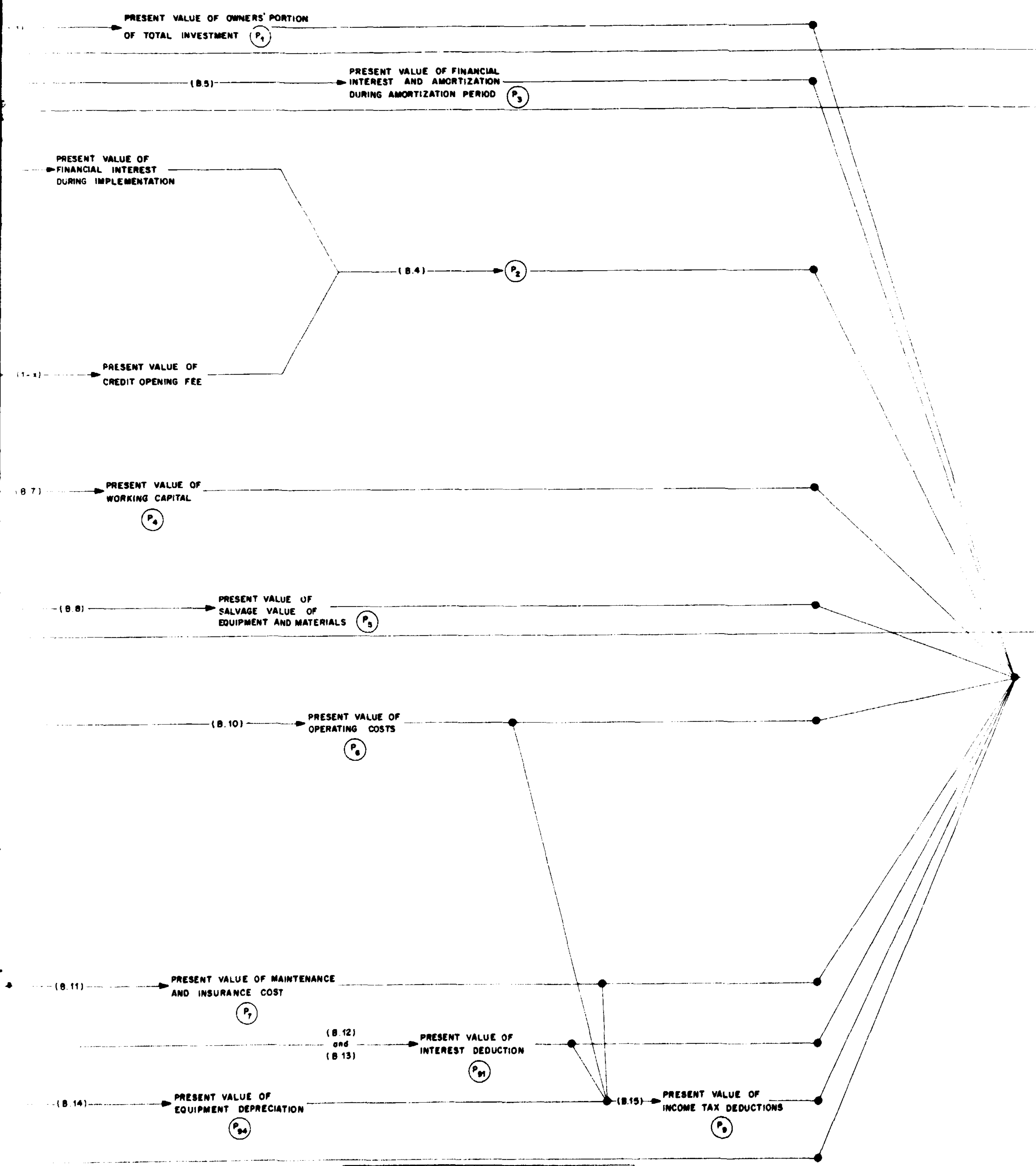
In order to exemplify model versatility ethanol selling price was also calculated for various return rates and for the financing prevailing in the Brasilian ProAlcohol (see Appendix A).

To calculate selling price, some parameters have to be fixed. The values adopted for each parameter in the exampe are shown below:

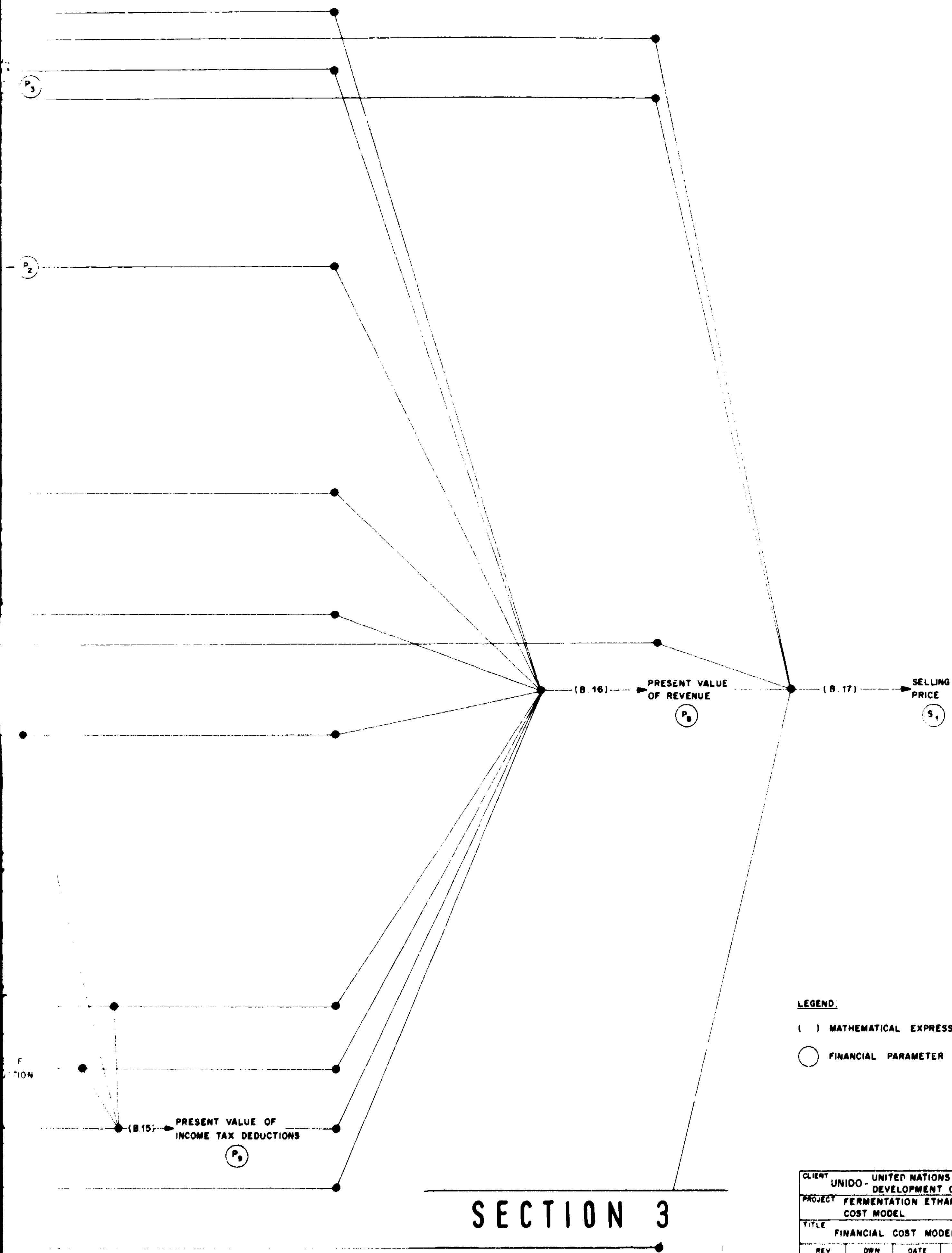
. Inflation rate: 40% p.a.
. Project life-span: 15 years
. Depreciation (linear): 10 years
. Salvage value: 5% of fixed investment
. Income tax rate: 35% over gross profit
. Operating period: 180 days per year.


FIXED INVESTMENT (C)
OWNERS' FIXED INVESTMENT (x%)
IMPLEMENTATION TIME (s)
ROI RATE (d)
ACTUAL MONETARY CORRECTION DUE (w)
ACTUAL INFLATION (i)
GRACE PERIOD (k)
FINANCIAL INTEREST RATE (j)
CREDIT OPENING FEE (∝)
AMORTIZATION TIME (n)
DIFFERENTIAL EQUIPMENT COST RELATIVE TO INFLATION (z)
WORKING CAPITAL (W)
USEFUL OPERATING LIFE (r)
SALVAGE VALUE (r)
DIFFERENTIAL PROCESS INPUT COST RELATIVE TO INFLATION (e_i)
PROCESS INPUT ANNUAL CONSUMPTION (E_i)
PROCESS INPUT UNIT COST (C_i)
NUMBER OF PROCESS INPUTS (g)
MAINTENANCE AND INSURANCE COST (μ)
INTEREST DEDUCTION TIME (f)
EQUIPMENT DEPRECIATION TIME (f)
INCOME TAX RATE (θ)
MAIN PRODUCT ANNUAL PRODUCTION (D_1)
(8.3)
DISCOUNT FACTOR (q)
(8.1)
PRESENT VALUE OF OWNERS' ... OF TOTAL INVESTMENT
(8.5)
(8.2)
PRESENT VALUE OF FINANCIAL INTEREST DURING IMPLEMENTATION
∝C(1-x)
PRESENT VALUE OF CREDIT OPENING FEE
(8.6)
(p)
(8.7)
PRESENT VALUE OF WORKING CAPITAL (P_4)
(8.8)
PRESENT ... SALVAGE ... EQUIPMENT ...
(8.9)
(h_i)
(8.10)
(8.11)
PRESENT VALUE OF ... AND INSURANCE (P_7)
(8.14)
PRESENT VALUE EQUIPMENT DEPR... (P_94)

SECTION 1


PRESENT VALUE OF OWNERS' PORTION OF TOTAL INVESTMENT (P1)
(B.5)
PRESENT VALUE OF FINANCIAL INTEREST AND AMORTIZATION DURING AMORTIZATION PERIOD (P3)
PRESENT VALUE OF FINANCIAL INTEREST DURING IMPLEMENTATION
(B.4)
(P2)
(1-x)
PRESENT VALUE OF CREDIT OPENING FEE
(B.7)
PRESENT VALUE OF WORKING CAPITAL (P4)
(B.8)
PRESENT VALUE OF SALVAGE VALUE OF EQUIPMENT AND MATERIALS (P5)
(B.10)
PRESENT VALUE OF OPERATING COSTS (P6)
(B.11)
PRESENT VALUE OF MAINTENANCE AND INSURANCE COST (P7)
(B.12) and (B.13)
PRESENT VALUE OF INTEREST DEDUCTION (P91)
(B.14)
PRESENT VALUE OF EQUIPMENT DEPRECIATION (P94)
(B.15)
PRESENT VALUE OF INCOME TAX DEDUCTIONS (P9)

SECTION 2



LEGEND:

( ) MATHEMATICAL EXPRESSION NUMBER

◯ FINANCIAL PARAMETER

SECTION 3

CLIENT UNIDO - UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION				
PROJECT FERMENTATION ETHANOL PRODUCTION COST MODEL				
TITLE FINANCIAL COST MODEL ALGORITHM				
REV	DWN	DATE	CHK	NO CT-UN01-006
0	CB/PC	27 08 80	CB	

TABLE 34

SUGARCANE INDEPENDENT DISTILLERY

- DISTILLERY FIXED INVESTMENT BREAKDOWN -

Basis: Daily capacity: 120 m^3 of absolute ethanol

COST ITEM	VALUE	
	(10^3 US$)	(%)
General and Administrative Expenses (a)	80	0.7
Management (b)	420	3.8
Site (c)	80	0.7
Technology Licensing (d)	100	0.9
Engineering and Procurement (e)	630	5.6
Equipment and Materials (f)	6 610	59.2
Civil Works and Erection (g)	2 200	19.7
Pre-Operation and Start-up Expenses (h)	50	0.4
Contingencies (i)	1 000	9.0
TOTAL	11 170	100

Notes:

(a) Includes expenditures on certificates, contracts, studies, feasibility study. Correspond to 0.7% of total fixed investment.

(b) Equivalent to an effort of 20,000 MH.

(c) Land acquisition and site preparation. Proportional to the ethanol output. For 120m^3 ethanol output a 3 ha area is required.

(d) Depends exclusively on owner of the technology.

(e) Includes basic design, detailed engineering, procurement, inspection and expediting. Equivalent to an effort of 30,000 MH or approximately 10% of "Equipment and Materials".

(f) Based on quotation of local manufacturers. Materials usually represent about 10% of this item.

(g) Based on effort of 800,000 MH. The total value is extremely dependent on wages and cost of materials of construction.

(h) Corresponding to the operating costs equivalent to 2 days of operation at full capacity.

(i) 9% of total fixed investment.

Ref.: (39; 40; 43)

TABLE 35

SUGARCANE INDEPENDENT DISTILLERY

- DISBURSEMENT SCHEDULE DURING IMPLEMENTATION -

Basis: Investor's own resources

Daily capacity -120m³ of absolute ethanol

MONTH OF IMPLEMENTATION	VALUE(a) (10^3 US$)
0	148
1	84
2	52
3	68
4	84
5	10
6	100
7	306
8	111
9	312
10	450
11	730
12	830
13	1 836
14	1 634
15	598
16	1 227
17	310
18	1 040
19	127
20	774
21	107
22	140
23	92
TOTAL	11 170

Note: (a) Current Value

FIGURE 13

SUGARCANE INDEPENDENT DISTILLERY

- CAPITAL DISBURSEMENT SCHEDULE DURING IMPLEMENTATION -

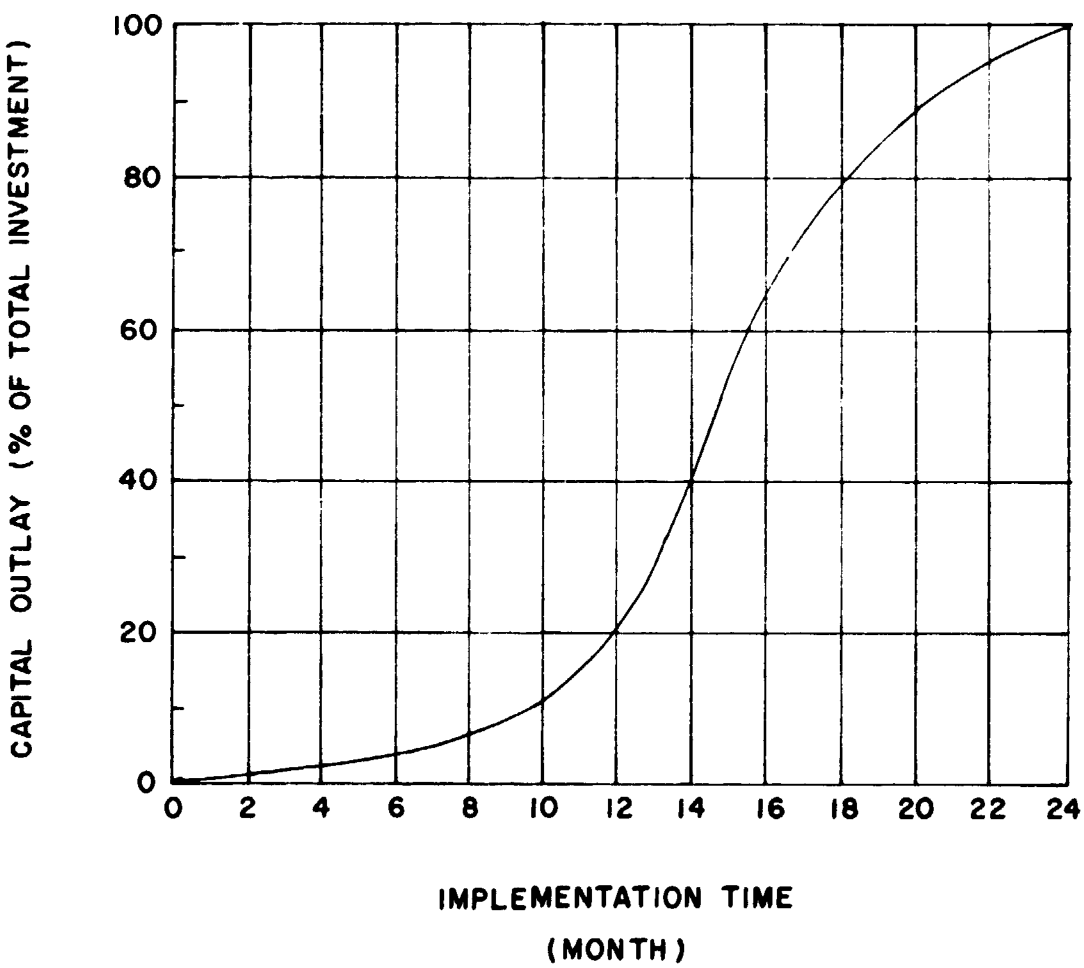


TABLE 36

SUGARCANE INDEPENDENT DISTILLERY

- STRUCTURE OF WORKING CAPITAL -

Basis: Rated Daily capacity: 120 m^3 of absolute ethanol

ITEM	UNIT	QUANTITY	US$/UNIT	VALUE (10^3US$)
CURRENT ASSETS				
. Minimum Cash Reserve[(a)]	-	-	-	99.0
. Inventories				
Sugarcane	t	1,800	12.34	22.2
Superphosphate	t	164	230	37.7
Ammonium Sulfate	t	162	240	38 9
Sulphuric Acid	t	216	130	28.1
Benzene	t	7	450	3.2
Pentachlorophenol	t	3	6,000	18.0
Material in Process[(b)]	m^3	200	330	66.0
Absolute Ethanol [(c)]	m^3	10,800	330	3,564.0
Hydrated Ethanol	m^3	50	300	15.0
Fusel Oil	t	28	200	5.6
Maintenance Materials and Operating Supplies	-	-	-	110.4
			Subtotal (1)	4,008.1
CURRENT LIABILITIES				
. Suppliers' Credit				
Superphosphate	t	82	230	18.9
Ammonium Sulfate	t	81	240	19.4
Sulphuric Acid	t	108	130	14.0
Benzene	t	3	450	1.4
Pentachlorophenol	t	2	6,000	12.0
			Subtotal (2)	65.7
TOTAL				4,073.8

Note: (a) 30 days of Expenses with Labor, Insurance and administrative expenses
(b) Expressed in terms of absolute ethanol
(c) Ethanol Administered Selling price.

Ref.: (15).

TABLE 37

SUGARCANE INDEPENDENT DISTILLERY

- PROCESS INPUTS CONSUMPTION AND PRICE -

Basis: Rated Daily Capacity: 120m^3 of absolute ethanol 180 days of operation per year

ITEM	UNIT/DAY	CONSUMPTION (UNIT / DAY)	PRICE (US$/UNIT)	VALUE (10^3US$/DAY)	% OF TOTAL
VARIABLE COSTS					
Sugarcane	t	1,800	12.34	22.21	79
Superphosphate	kg	2,725	0.23	0.63	2
Ammonium Sulfate	kg	2,700	0.24	0.65	2
Sulphuric Acid	kg	3,600	0.13	0.47	2
Benzene	kg	110	0.45	0.05	-
Pentachlorophenol	kg	50	6.00	0.30	1
Water	m3	2,200	0.02	0.04	-
Stillage Treatment	m3	1,560	0.18	0.28	1
			Subtotal (1)	24.63	87
BY-PRODUCTS CREDIT					
Hydrated Ethanol	m3	5	300	(1.51)	(5)
Fusel Oil	kg	465	0.20	(0.09)	-
			Subtotal (2)	(1.60)	(5)
FIXED COSTS					
Labor[(a)]	MH	850	2.10	1.79	6
Administrative[(b)] Expenses	-	-	-	0.89	3
Maintenance[(c)]	-	-	-	1.84	7
Insurance[(d)]	-	-	-	0.62	2
			Subtotal (3)	5.14	18
TOTAL	-	-	-	28.17	100

Note: (a) Includes wages and all social charges (56% of wages)
(b) 40% of labor
(c) Annual maintenance cost is calculated at 5% of investment in equipment and material
(d) Annual insurance cost is based on a percentual of 1% over fixed investment.

The results of financial analysis are shown in Tables 38 and 39. The benefits resulting from adoption of subsidized financing can be visualized in Figure 14 where fuel ethanol administered price was shown as a reference.

For the current market price of alcohol, US$ 332/m^3 (administered by the Brasilian Government) the ROI on owner's investment is 8% p.a. whereas ROI on investment under PROALCOHOL financing is 21% p.a. current gasoline retail price is US$ 560 per m^3 (US$ 2.12 per US gallon). If alcohol could be sold at the gasoline retail price ROI on owner's investment would be only 27% p.a.

TABLE 33

SUGARCANE INDEPENDENT DISTILLERY

- BREAKDOWN OF SELLING PRICE -

Basis: PROALCOHOL FINANCING
Daily Ethanol Output: 120m³

COST ITEM	VALUE AS A FUNCTION OF ROI (% p.a.)									
	5		10		15		20		25	
	US$/m³	% OF TOTAL PRICE	US$/m³	% OF TOTAL PRICE	US$/m³	% OF TOTAL PRICE	US$/m³	% OF TOTAL PRICE	US$/m³	% OF TOTAL PRICE
. Variable Costs										
Raw Material	185	72	185	66	185	61	185	56	185	52
Chemicals / Utilities	18	7	18	6	18	6	18	5	18	5
Stillage Treatment	2	1	2	1	2	1	2	1	2	1
Byproducts Credit	(13)	(5)	(13)	(5)	(13)	(4)	(13)	(4)	(13)	(4)
. Fixed Costs										
Labor	15	5	15	5	15	5	15	5	15	4
Maintenance	15	5	15	5	15	5	15	5	15	4
Insurance	5	2	5	2	5	2	5	2	5	1
Administrative Expenses	7	3	7	3	7	2	7	2	7	2
. Taxes	2	1	9	3	16	5	24	7	33	9
. Depreciation	17	7	17	6	17	6	17	5	17	5
. Profit	5	2	20	7	36	10	53	15	71	20
Selling Price	258	100	280	100	303	100	328	100	355	100

TABLE 39

SUGARCANE INDEPENDENT DISTILLERY

- BREAKDOWN OF ETHANOL SELLING PRICE -

Basis: Owners' Resources only
Daily Ethanol Output: $120 m^3$

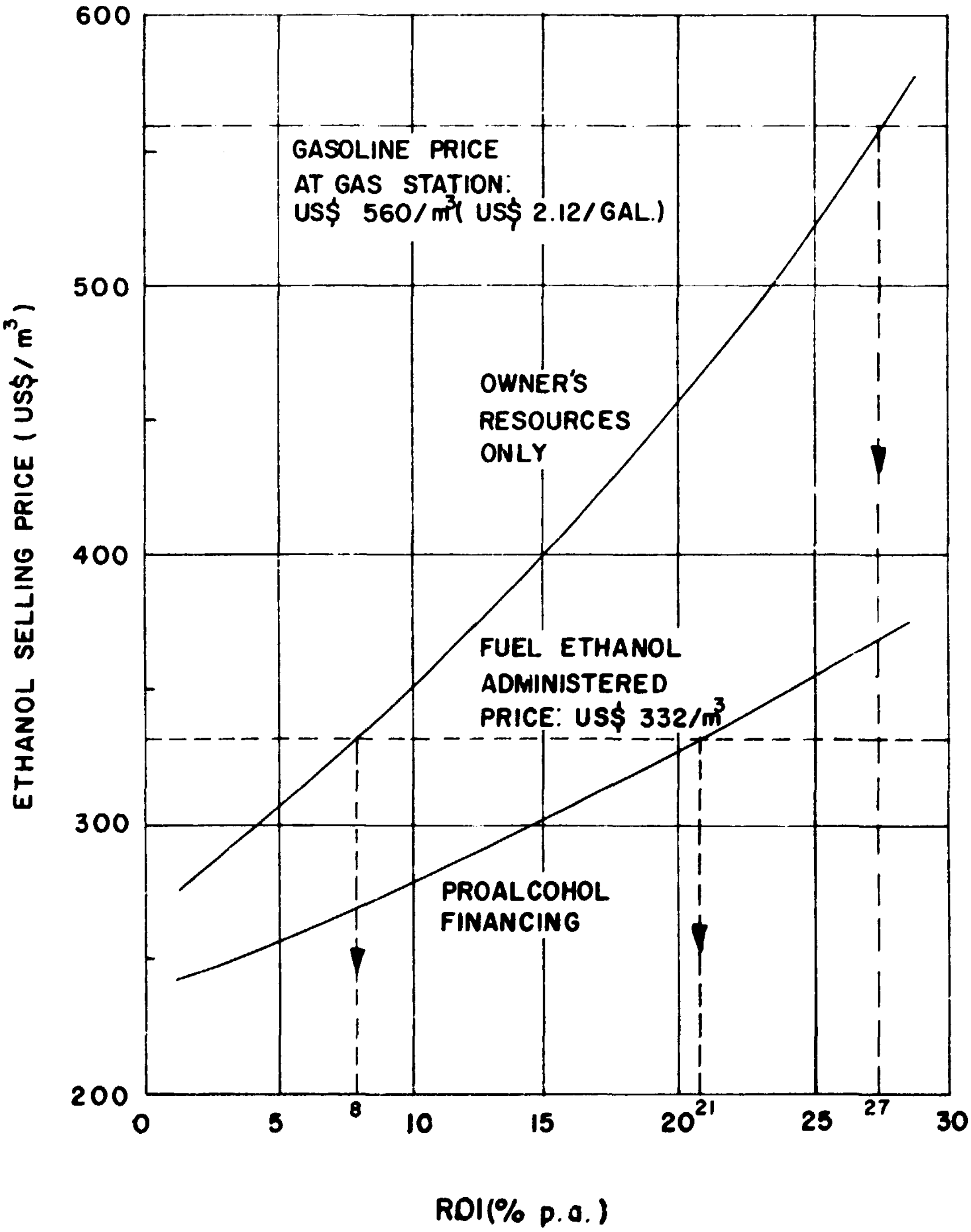
COST ITEM	VALUE AS FUNCTION OF ROI (% p.a.)									
	5		10		15		20		25	
	US$/$m^3$	% OF TOTAL PRICE	US$/$m^3$	% OF TOTAL PRICE	US$/$m^3$	% OF TOTAL PRICE	US$/$m^3$	% OF TOTAL PRICE	US$/$m^3$	% OF TOTAL PRICE
. Variable Costs										
Raw Material	185	61	185	53	185	46	185	40	185	36
Chemicals Utilities	18	6	18	5	18	5	18	4	18	3
Stillage Treatment	2	1	2	1	2	1	2	0.4	2	0.4
Byproducts Credit	(13)	(5)	(13)	(4)	(13)	(3)	(13)	(3)	(13)	(2)
. Fixed Costs										
Labor	15	5	15	4	15	4	15	3	15	3
Maintenance	15	5	15	4	15	4	15	3	15	3
Insurance	5	2	5	1	5	1	5	1	5	1
Administrative Expenses	7	2	7	2	7	2	7	2	7	1
. Taxes	20	7	35	10	52	13	72	16	94	18
. Depreciation	17	6	17	5	17	4	17	4	17	3
. Profit	33	10	63	19	97	22	135	29	176	33
Selling Price	304	100	349	100	400	100	458	100	521	100

FIGURE 14

SUGARCANE INDEPENDENT DISTILLERY

- SENSITIVITY OF ETHANOL SELLING PRICE TO ROI -

BASIS: RATED DAILY CAPACITY: 120 m^3 OF ABSOLUTE ETHANOL



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A. BRASILIAN NATIONAL ALCOHOL PROGRAM - PROALCOHOL

A.1 Program Development

A.1.1 Objectives of the Program

The supply of primary energy in Brasil, traditionally based on local, renewable resources (hydroelectricity, firewood, charcoal, coal, sugarcane bagasse) has undergone a radical transformation in recent decades, due to the increased use of petroleum as an industrial and automotive fuel.

As shown in Figure 15, petroleum replaced biomass and became the main source of primary energy slightly more than ten years ago.

The growing consumption of fossil fuels is associated with Brasil's industrial expansion, in which the motor vehicle manufacturing industry has played a significant part since its cornerstone was laid in 1957. Evidence of this scenario is the annual 9.5% increase in the demand for oil, compared to the annual 7.2% growth of the overall demand for primary energy over the last decade.

Analysis of Figure 15 shows that natural gas (almost nihil) and oil consumption in 1978 was of the order of 47 million TOE, or about 43% of the total domestic energy demand. Imports accounted for 85% of that total, while domestic oil and gas output remained at the ten-year level.

The recent escalation of international oil prices dramatically underscored Brasil's dependence on imported fuels. It is estimated that the cost of imported oil in 1979 amounted to half the nation's total expenditures on imports. A striking imbalance in the balance of payments and the lower GNP growth rate are some of the direct influences of that dependence on foreign oil.

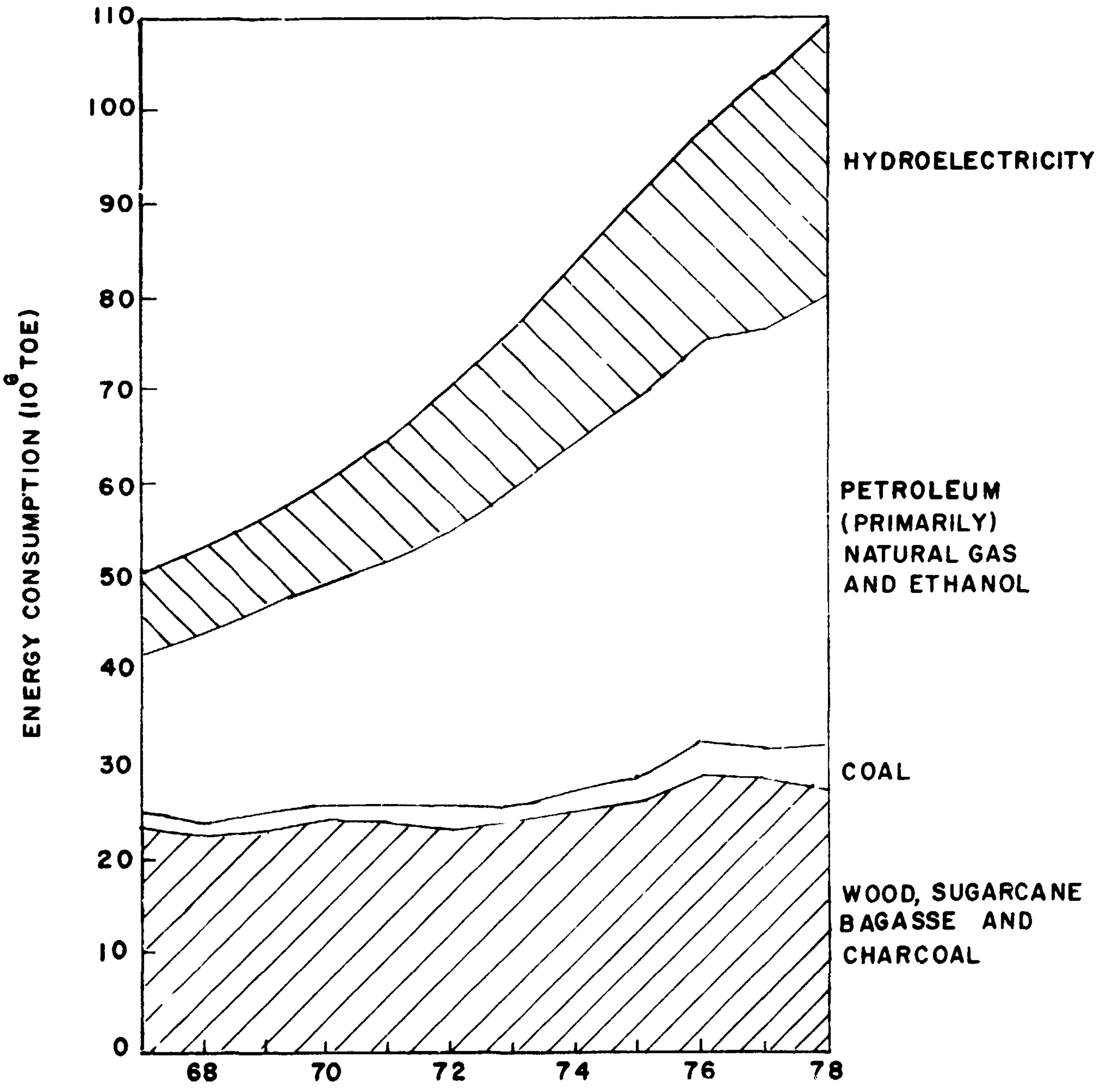
Higher sugar prices on the international market stimulated efforts by sugar producers in 1972-73 to expand their productive capabilities. Then the subsequent drop in world sugar prices discouraged Brasilian sugar exports and caused a deep economic crisis in the sector. Large production surpluses have accumulated since that price decline.

In addition to other political and social factors, the combined effect of falling sugar prices and soaring oil costs were the main motives for the creation of the National Alcohol Program - ProAlcohol or PNA in October, 1975.

Among the major responsibilities and goals of the proposed program is a definition of the criteria to be observed in locating new distilleries, with the following objectives in mind:

FIGURE 15

THE BRASILIAN PRIMARY ENERGY CONSUMPTION PROFILE



NOTE: TOE - TON OF OIL EQUIVALENT

REF: (17)

- Increasing the growing of sugarcane and other biomasses for energy purposes, thanks to Brasil's evident vocation as an agricultural country with an abundance of suitable soils, climate and water;

- Reducing the dependence of foreign energy sources and feedstocks, through large-scale use of local renewable resources such as ethanol;

- Reducing regional imbalances and improving the per capita distribution of income by expanding and increasing the Nation's agroindustrial activities associated with the production of alcohol;

- Dynamizing the capital goods sector through the increased demand for equipment to expand and build new distilleries;

- Minimizing the costs of transporting feedstocks and energy sources;

- Reducing expenditures for imported oil, thus directly benefiting the balance of payments.

Establishing specifications for the use and programming the annual production capacity of individual distilleries are included in ProAlcohol responsibilities.

Although not explicitly stated in the original text, the Program's initial goals also include the following objectives:

- Utilization of the sugar agroindustry's capacity, idled by curtailed foreign demand;

- Gradual replacement of up to 2% of the national consumption of automotive gasoline by blending it with anhydrous or absolute alcohol;

- Increased production of chemicals derived from alcohol (ex.: ethylene) to replace petrochemical feedstocks, stimulated by the availability and guaranteed supply of ethyl alcohol.

An output of 5 billion liters of alcohol for 1985 was originally forecast. In 1979 the PNA was reformulated and a target output of 10.7 billion liters was set for 1985, including the gradual utilization of hydrated ethyl alcohol (96° G.L.) as a straight automotive fuel. It would be implemented gradually with increasing number of vehicles powered exclusively by alcohol.

Although considered as highly optimistic, the Government's goals reflect its strong intention to increase the use of ethanol and introduce it definitely on the domestic energy market. The program's orientation to boost the production of hydrated alcohol will significantly alter existing production profile.

It is anticipated that up to 85% of the 1979/80 sugarcane harvest will be utilized in the production of anhydrous alcohol (See Figure 16).

There are three distinct phases in the evolution of the ProAlcohol:

PHASE 1 : Period prior to ProAlcohol creation in 1975, when alcohol was considered as a by-product of the sugar industry and only surpluses could be diverted for other purposes.

PHASE 2 : ProAlcohol implementation period (1976-79), when the volume of alcohol produced climbed quickly, based mainly on production by molasses distilleries using the existing sugar agroindustry infrastructure. This phase corresponded to the saturation of the existing capacity for producing alcohol from molasses and to the increased use of mixed cane juice based on the direct utilization of part of the cane usually intended for sugar production together with molasses. It is estimated that the coming years will see increased grinding and milling allotments for juice enrichment and also for direct production of alcohol at the start and end of the harvest period.

PHASE 3 : The consolidation period corresponds to increased supply of alcohol from independent distilleries based exclusively on new sugarcane-growing areas and/or different raw materials (mandioca, sweet sorghum, wood, etc.).

It is clear however that the process of diversifying raw materials and separating alcohol production from sugar manufacture will necessarily require establishing independent distilleries. The timely implementation of those new agroindustrial complexes, calling for substantial capital outlays and strict compliance with agricultural and industrial timetables, constitute the major challenge now facing ProAlcohol's development.

A.1.2
Effects of the Program

This section discusses ProAlcohol's results in the context of Brasil's sugar-producing sector, as well as the Program's future scenario based on governmental projections.

Figure 17 presents the evolution of domestic sugar production over the 1970-78 period. ProAlcohol creation is seen to coincide with the slump in international sugar prices, however Brasil's output regained its previous levels and the growth rate in 1979 was the highest recorded during the period. It is clear that most of the sugar produced (about 80%) is routed for internal consumption, although the volume exported equals 1974 levels.

FIGURE 16

HISTORIC AND FORECAST OF ETHANOL PRODUCTION IN BRASIL

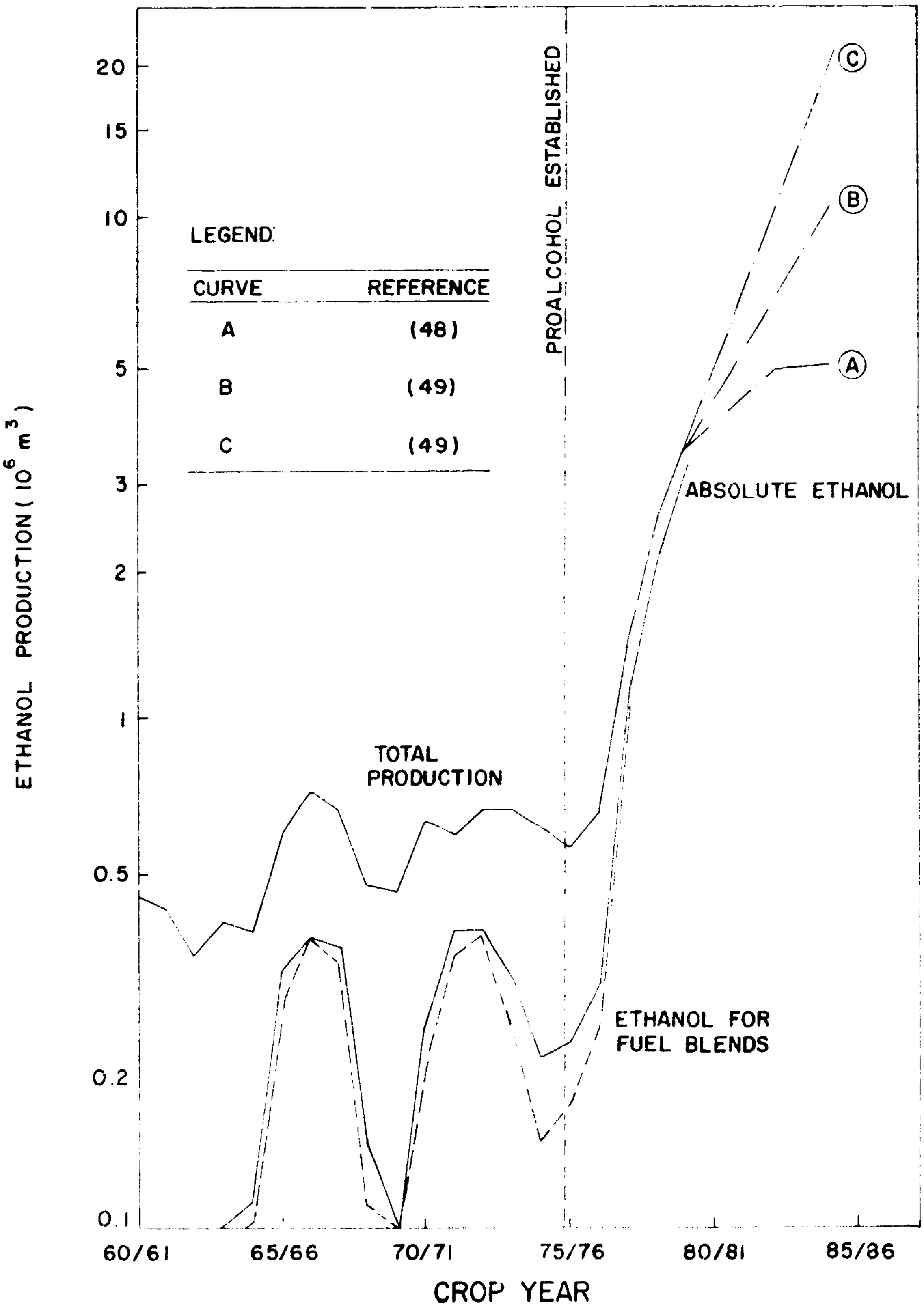
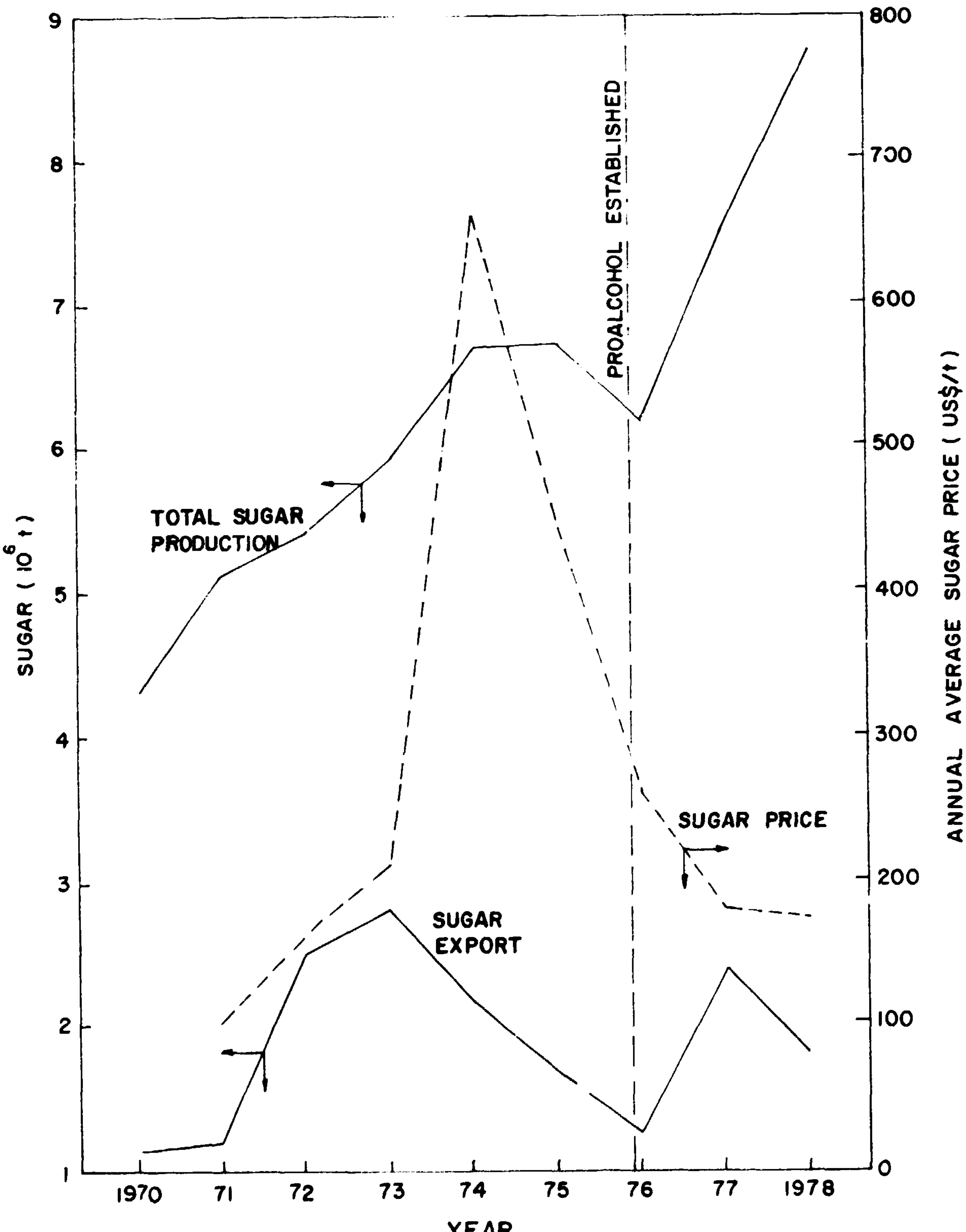


FIGURE 17

BRASILIAN SUGAR PRODUCTION AND EXPORT AND SUGAR PRICE EVOLUTION ON THE WORLD MARKET



REF: (50,51,52)

The evolution of the area dedicated to growing sugarcane is illustrated in Figure 18. The pattern of cultivation is seen to have followed the production of sugar closely. ProAlcohol's influence has been slight with respect to expanding the cane-growing areas exclusively for alcohol production. Observation indicates that most alcohol has been produced at molasses distilleries (Figure 19) where a large portion of the cane initially intended for sugar manufacture is transformed directly into alcohol. If it is assumed that the planted area growth rate remains constant with the rate observed over the past 15 years, the forecast for 1975 will be 2.5 million hectares.

This amounts to about 0.3% of Brasil's land mass, or about 35% of the land with soil and climatic characteristics favorable to sugarcane cultivation. If this rate of growth accompanied the evolution of domestic sugar production, the area in 1985 would be 2.8 million hectares or 40% of the total area on which sugarcane can be grown. The direct effect of ProAlcohol will be felt only as virgin areas are utilized to grow cane for alcohol production at independent distilleries.

Table 40 illustrates the total sugarcane ground at mills and distilleries, the distribution in the North-Northeastern and South-Central regions, and the source of milled cane (whether from mill-owned plantations or supplied by independent cane growers) for the 74/75 and 77/78 harvests, prior to and after the Program was created. The number of sugar/alcohol-producing units is also compared for the two regions and harvests.

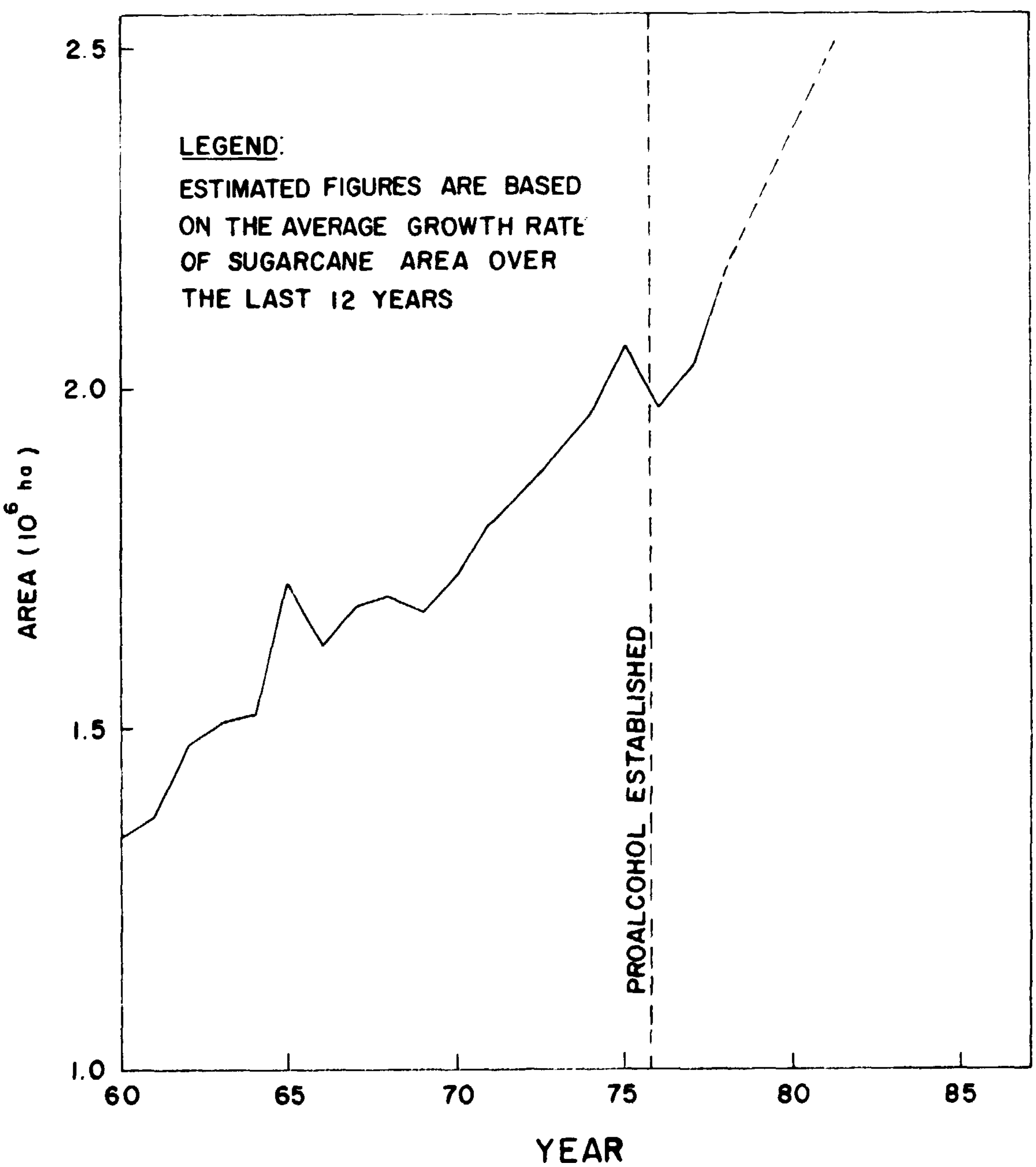
Federal Decree-Law 4870 determined that from 1965 onwards at least 60% of the cane consumed at a mill or distillery should be provided by independent suppliers. The reality, however, is quite different, as independent suppliers see their percentage continually diminished.

A close look at Table 40 will show that the percentage of total cane provided from mill or distillery-owned plantations is actually increasing. This indicates, in turn, a marked concentration of income for mill and/or distillery owners, although the output of cane increased 36% over the period. The number of cane-milling units also decreased due to the economy of scale benefits derived from industrial mergers. Production concentration was also a result of Decree-Law 1186 enacted in 1971, which envisioned higher productivity rates through economy of scale resulting from company consolidation, acquisition, mergers, etc. Regardless of the economic effects, the repercussions from the social standpoint were undesirable and clashed with ProAlcohol's objectives of improving income distribution and diminishing regional disparities.

The evolution of the volume of alcohol produced, in terms of type of distillery and cane-growing region, is shown in Figures 19 and 20, respectively. The projections are based on the information contained on the list of approved projects of ProAlcohol.

FIGURE 18

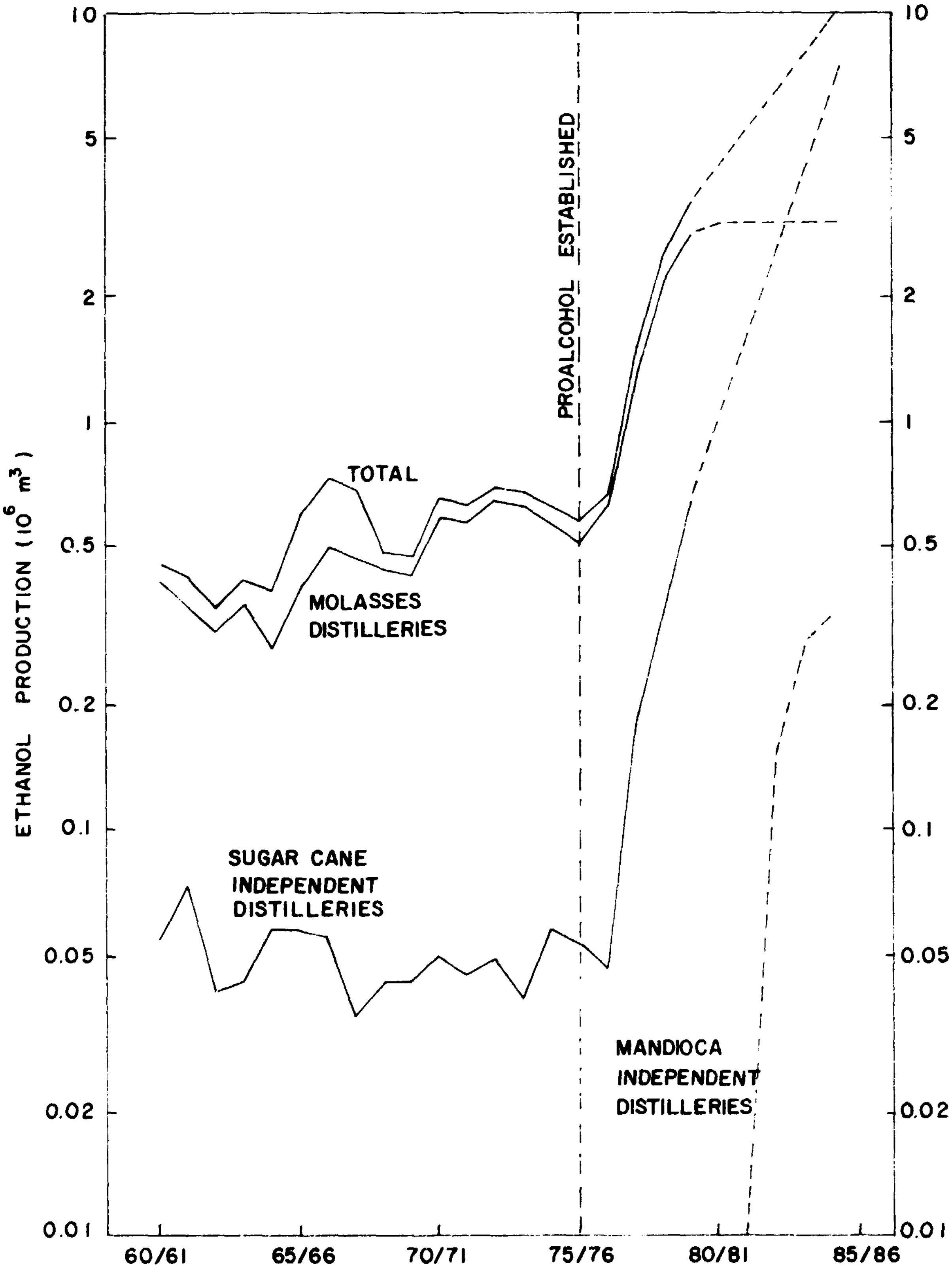
SUGARCANE AREA EXPANSION IN BRASIL



REF: (52,53)

FIGURE 19

HISTORIC AND FORECAST OF ETHANOL PRODUCTION AS A FUNCTION OF DISTILLERY TYPE



REF: (48,50,54)

TABLE 40

SOURCES FOR MILLED CANE AND NUMBER OF SUGAR MILLS

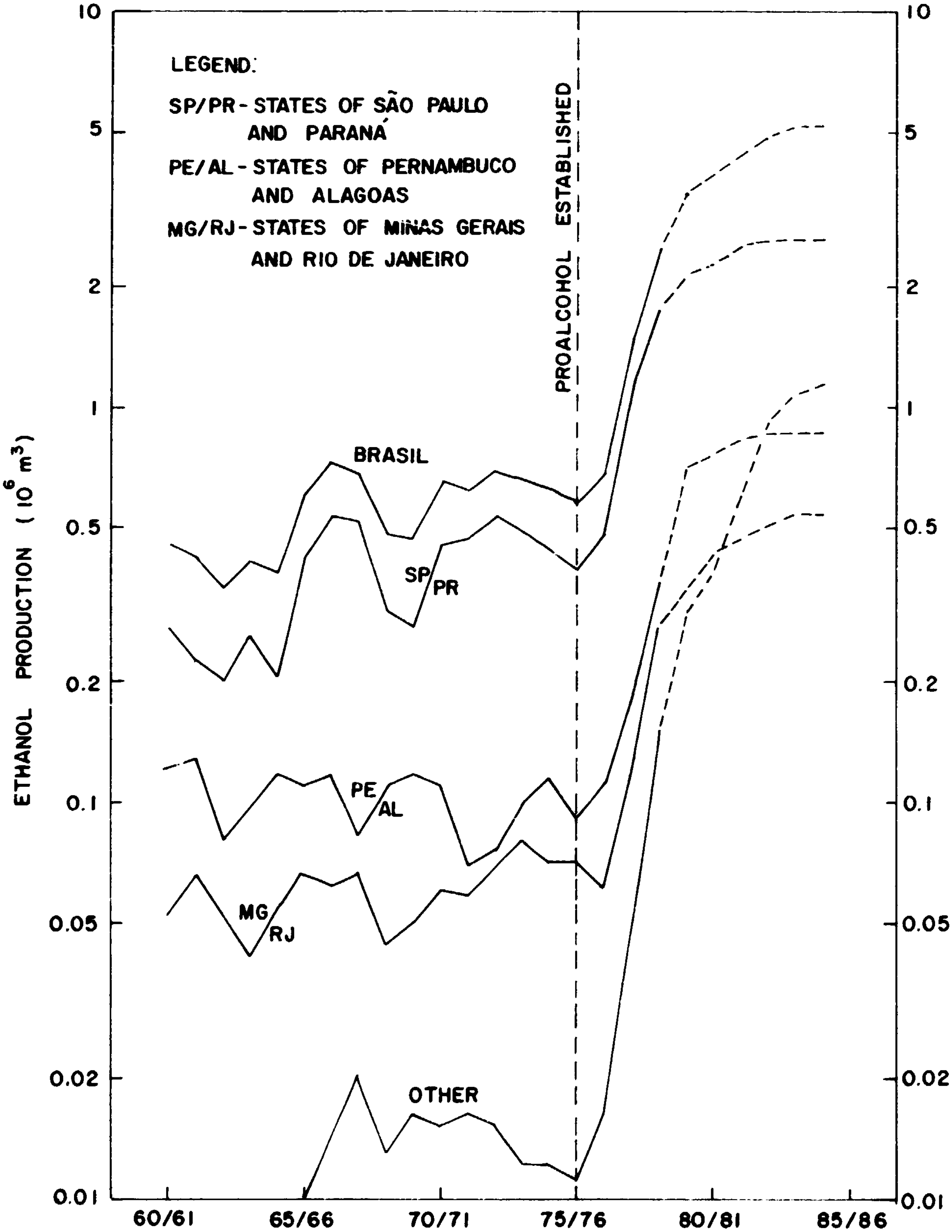
- GEOGRAPHIC DISTRIBUTION IN 1974/75 AND 77/78 HARVESTS -

I T E M	UNITY	R E G I O N				B R A S I L	
		NORTH	NORTHEAST	CENTRAL / SOUTH		T O T A L	
		74/75	77/78	74/75	77/78	74/75	77/78
MILLED CANE							
. Total	10^6 t	27.7	35.6	46.8	65.7	74.5	101.3
. Suppliers	% total	61	41	39	35	47	37
Number of sugar Mills/Distilleries	-	89	84	127	122	216	206

Ref.: (54; 55)

FIGURE - 20

REGIONAL HISTORIC AND FORECAST OF ETHANOL PRODUCTION IN BRASIL



REF. (48,50,54)

. The total quantity of ethanol produced during the last harvest was 4.6 times the values of the 75/76 harvest prior to the creation of the Program, and was mainly in anhydrous alcohol (85%);

. Up to the 1978/79 harvest, molasses distilleries produced more than 80% of the total volume. This figure will probably decrease to an estimated 50% for the 84/85 harvest. The independent distilleries with a slight share (13%) of the 1978/79 harvest will have tripled that percentage for the 84/85 harvest.

. The States of São Paulo and Paranã, mainly the former, accounted for 70% of the total volume of ethanol produced from the 1978/79 harvest. This percentage will probably decline to 50% for the 1984/85 harvest, according to the authorized production capacities set forth in March, 1980;

. The inclusion of other non-traditional cane-growing areas will lead to an output equivalent to 20% of the total forecast in 1985.

Table 41 depicts the percentage of anhydrous alcohol used in the gasohol blend. Analysis of this table discloses that the national goal of a 20% alcohol/80% gasoline mixture has been achieved in the State of São Paulo (which produces 70% of Brasil's alcohol) whereas two thirds of that goal has been attained in national terms in 1979.

A.1.3
Attaining the ProAlcohol's Objectives

Since its inception, ProAlcohol has been regarded as an important element not only for solving the domestic energy problem, but also as a means of national social and economic development. Thus it was anticipated that it would be used as an instrument to: level regional income distribution disparities, because the low-income regions possess suitable conditions for the production of feedstocks; reduce individual income disparities, because alcohol production is a labor-intensive activity; boost domestic income by utilizing idle production factors, land and manpower; and expand domestic capital goods production.

Prior to the start of ProAlcohol in 1975, 150 distilleries had an effective production of 556 thousand m^3 annualy, but were subject to 50% idle time. Up to March 21, 1980, ProAlcohol National Executive Commission (CENAL) has approved 260 projects that included distillery expansion projects, of which 144 were expected to be operational for the 1979/80 harvest. According to the CENAL Schedule, the 260 distilleries would be operational for the 1984/85 cane harvest, enabling production of 6.0 million m^3 of ethanol to be attained.

TABLE 41

ETHANOL CONTENT OF BRASILIAN GASOHOL

YEAR	GASOHOL ($10^6 m^3$)	ETHANOL CONTENT (%)	
		SÃO PAULO STATE	BRASIL
1972	11.9	8.6	3.5
1973	13.9	7.0	2.5
1974	14.3	3.1	1.4
1975	14.6	2.4	1.1
1976	14.7	2.6	1.2
1977	14.1	8.2	4.8
1978	15.2	20.0	11.1
1979	15.7	20.0	14.2

Ref.: (50; 56)

Table 42 illustrates the evolution of alcohol production after 1975. Analysis of that reveals that ProAlcohol initial production goal of 5 million m^3 in 1985 will be easily reached. But this statement can not be made with respect to decreasing regional income disparities. Although the Northern-Northeastern regions may produce 30% of the total ethanol output expected for the 1984/85 harvest, this percentage will still be substantially below what could have been attained through better utilization of the land available for this purpose in those regions.

Drawing No. CT-UN01-007 illustrates the disparity among Brasil's five geoeconomic regions, with respect to consumption of fuel alcohol and the three main crude oil fractions, namely fuel oil, diesel oil and gasoline.

With regard to the question of individual income disparities, it can be stated that ProAlcohol stimulated the creation of about 32,000 new jobs directly in the rural areas, or about 40 jobs per thousand m^3/year. Conversely, Figure 21 could be used to argue that the goal of decreasing the individual income disparities has not been achieved, in view of the fact that the Program is based on large- scale distilleries generally characterized as prone to income-concentrating.

It is worth mentioning that the attainment of the goals anticipated for the 79/80 harvest will be possible only because of low international sugar prices and the existence of idle capacity in the sugar/alcohol agroindustry. Therefore, the alcohol-producing agroindustry, which had been acting as a relief valve for the sugar industry until ProAlcohol was created, continues to have its production linked to the international sugar market inasmuch as 85% of the alcohol produced in Brasil during the 78/79 harvest came from molasses distilleries. Approximately 70% of the output of the harvest came from the direct production of alcohol. This percentage corresponds to the amount of cane diverted from sugar production to the production of alcohol, which shows that the majority of the molasses distilleries presently operating in Brasil are operating in the same way as independent distilleries, i.e., producing alcohol directly from sugarcane in addition to molasses.

Within limits set by Government Regulations the sugar mill owner can "decide" at the last minute at the mill, and in terms of the sugar market what to do with the cane. This decision has led to larger and larger outputs of alcohol, but the situation is connected with the international sugar market. Because there is potentially a larger profit margin in sugar production, the present tendency could be suddenly reversed if the sugar market should become attractive again. Figure 22 illustrates the foregoing comments.

Diversifying raw materials used in alcohol production could modify this scenario. Implementing small alcohol-producing units in Brasil's interior regions, where their output could be used to supply small communities, is another alternative.

TABLE 42

HISTORIC AND FORECAST OF ETHANOL PRODUCTION

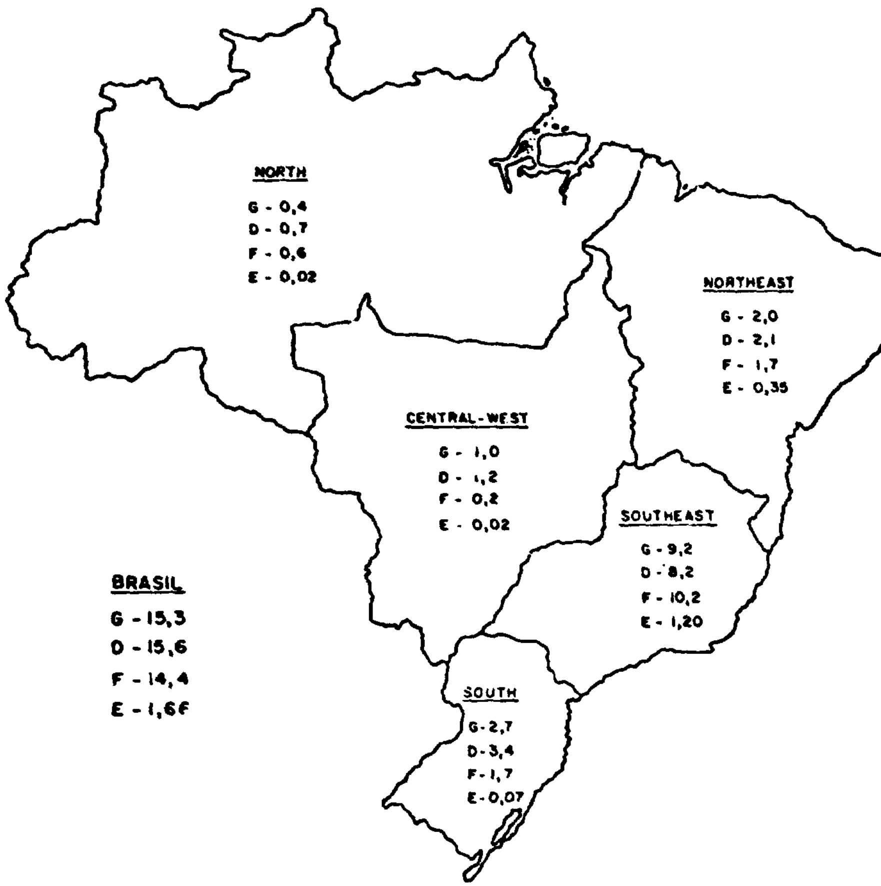
PER BRASILIAN REGIONS

HARVEST	P R O D U C T I O N					
	NORTH	NORTHEAST	CENTRAL	SOUTH	BRASIL	
	($10^3 m^3$)	(%)	($10^3 m^3$)	(%)	($10^3 m^3$)	(%)
75/76	102	18	454	82	556	100
76/77	114	17	550	83	664	100
77/78	292	18	1,290	82	1,582	100
78/79	403	16	2,080	84	2,483	100
79/80 (a)	881	23	2,916	77	3,797	100
84/85 (b)	1,775	2	3,729	68	5,504	100

Notes: (a) Estimated by IAA - Brasilian Sugar and Alcohol Institute for 79/80

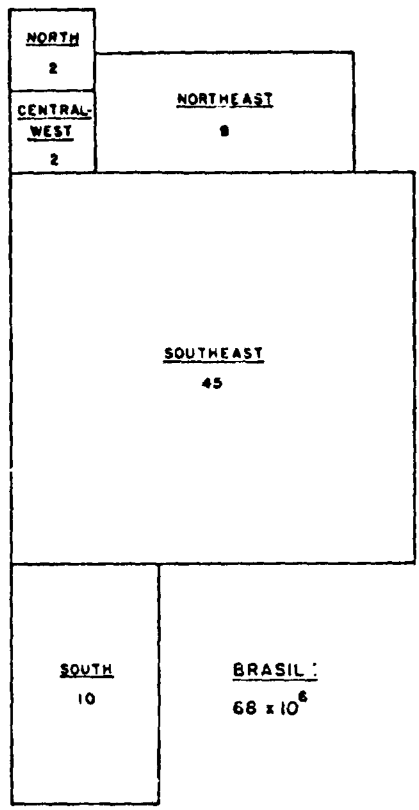
(b) Based on the rated capacity of distilleries, authorized by CENAL (up to 20.08.79) to be implemented by 1984/85.

Ref.: (48; 50; 54)



SYMBOL	FUEL	UNITY
G	GASOLINE	10^6 m^3
D	DIESEL OIL	10^6 m^3
F	FUEL OIL	10^6 m^3
E	FUEL ETHANOL	10^6 m^3

REGIONAL ENERGY CONSUMPTION (10^6 TOE)



SCALE: 1cm² is EQUIVALENT TO 680 x 10^3 TOE

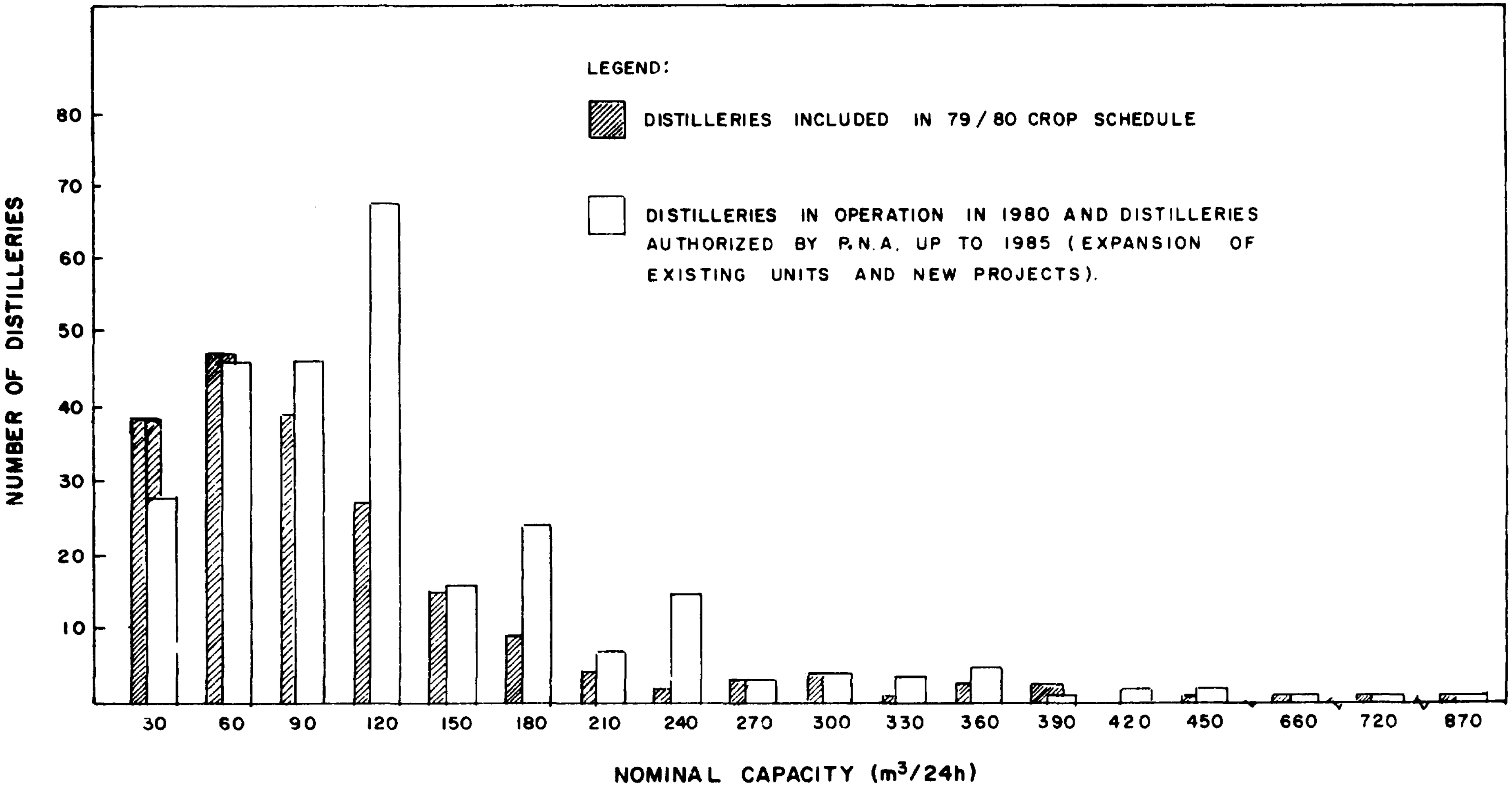
NOTE: TOE - TONS OF OIL EQUIVALENT

PROJECT: FERMENTATION ETHANOL PRODUCTION COST MODEL				
TITLE: BRASIL: REGIONAL ENERGY CONSUMPTION DISTRIBUTION (1978)				
REV	DWN:	DATE:	CHK:	NO. CT-UN01-007
0	CB/PC	22.05.80	CB	

FIGURE 21

DAILY CAPACITY SIZE DISTRIBUTION OF ETHANOL DISTILLERIES
- BRASIL -

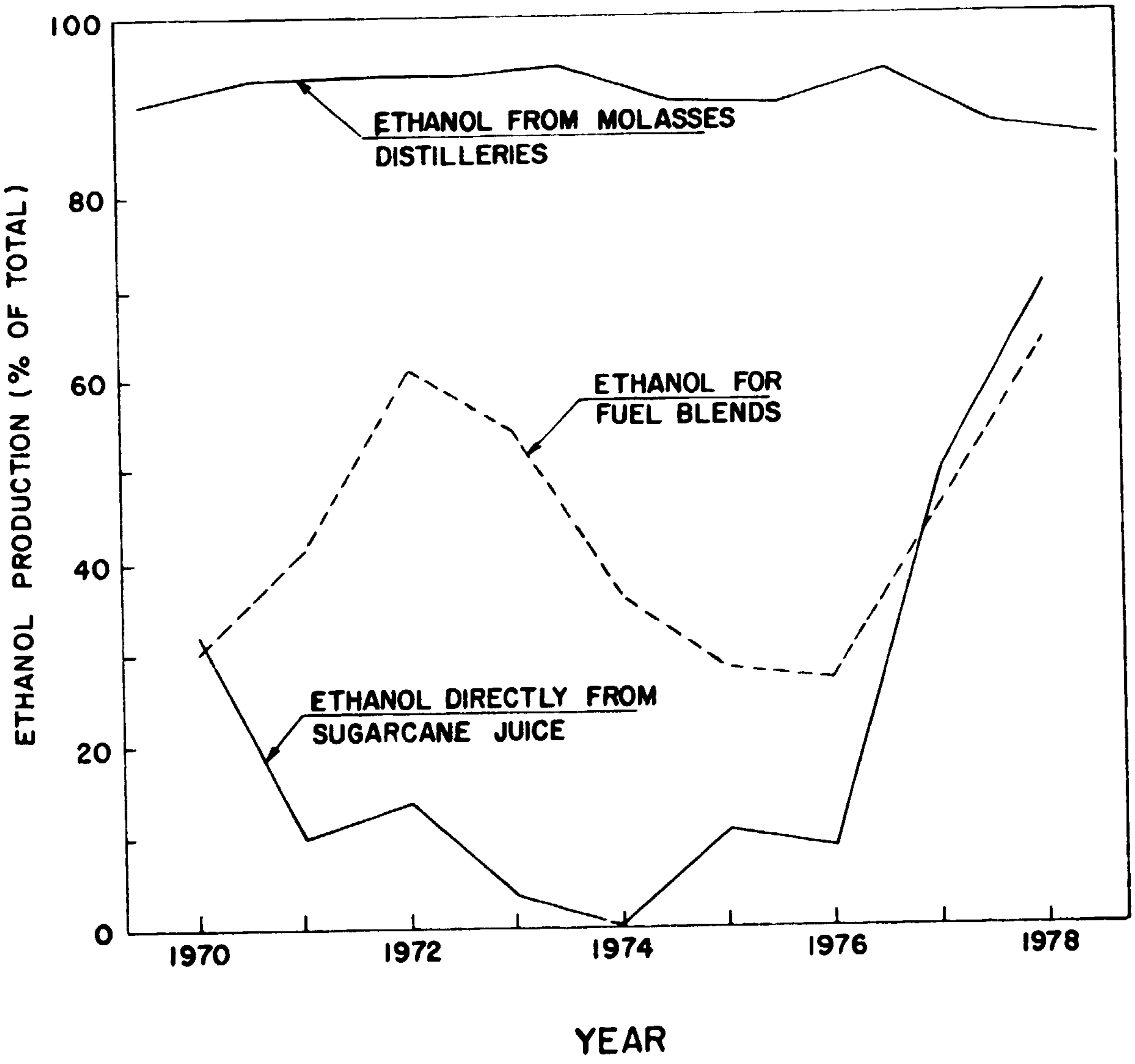
BASES: SUGARCANE DISTILLERIES OPERATING 180 DAYS/YEAR
MANDIOCA DISTILLERIES OPERATING 300 DAYS/YEAR



REF: (48,57)

FIGURE 22

SUGARCANE ETHANOL PRODUCTION



REF: (54,58)

The utilization and development of new crops like mandioca and sweet sorghum on untilled lands now unsuitable for growing food crops would enable generally low-income regions to produce fuel at least for their own needs. For strategic reasons, moreover, raw materials diversification is necessary to prevent the fuel alcohol production from becoming affected by storms or diseases afflicting the sugarcane crop.

In order to lower the costs of transporting small amounts of alcohol to inland regions located far from the transitional cane-growing areas, the implementation of small units based on local crops is envisioned.

The concept of macro and micro-distilleries is directly related to production capacity and purposes. Micro-distillery is the term normally used for a low-cost unit with a daily production of up to 5 m^3. The output is intended to supply the energy requirements of small rural properties, making them self-sufficient through the implementation of an integrated system with byproduct utilization.

The macro-distillery is a unit whose daily output exceeds 30m^3 and is intended mainly to provide alcohol at high industrial yield rates to supply urban centers with the liquid fuel.

Each type of unit presents intrinsic advantages with respect to its specific objective. The micro-distillery envisages production with low capital outlay for industrial investment while also affording the following advantages:

. Decentralization of energy production by distributing a large number of units across the country;

. Keeping the rural population in the area by creating direct jobs in the alcohol production process and indirect employment in other industrial activities that would follow and be set up in the region;

. Raising individual standards of living;

. Reducing the transport of feedstocks and final energy forms, which at the macro-distilleries presently amounts to diesel consumption equivalent to roughly 20% of the alcohol output;

. Possibility of implementing integrated systems, with rational by-products utilization;

. Utilization of the ethanol production potential in specific regions where large-scale production is unfeasible.

The macrodistillery envisions low-cost, high-yield alcohol production. The following advantages are anticipated:

. Economy of scale with respect to the industrial investment;

. Large-scale production enables the Program's goals to be attained;

. Lower-unit production costs.

However, the high capital investment involved in setting up these units is the main restricting factor. At these capacities managerial problems also arise reflecting the necessity of continuous feedstock supply and normal distillery operation.

A.2
Ethanol Price Regulations

Brasilian ethanol market prices are controlled by IAA - Brasilian Sugar and Alcohol Institute, based on a "parity price" whereby alcohol price is directly connected to sugar price. This relationship is based on the "economic" equivalence of producing alternatively ethanol or sugar/molasses from cane.

The "technical parity" used for the calculations is manipulated by IAA. The current value is 39 liters of ethanol per 60 kilograms of sugar plus 23.65 kilograms of molasses containing 55% of TRS (Total Reducing Sugars).

IAA regularly sets forth Regulatory Acts where it stipulates price values for absolute and hydrated ethanol, depending on its water content and final use:

. Industrial alcohol:	price inclusive of all pertinent taxes (ICM, IPI, PIS) and IAA contribution.
. Fuel alcohol:	price exempt of taxes and including a benefit equivalent to the taxes levied on the raw material (sugarcane). This is the so-called Acquisition Value to the Producer.
. Petrochemical feedstock:	Price including IAA contribution and PIS tax equivalent to industrial alcohol. In this case parity price is calculated as a percentage of petrochemical ethylene price.

Table 43 presents the breakdown of ethanol selling prices as established by IAA as of May 1980 (24) for the Central-South region.

Thus a single fuel ethanol price is practiced in Brasil, independent of its origin and tied up to the sugar price in the domestic market. For the present stage of the Alcohol Program, the ethanol market price remunerates the operating costs and capital invested in distilleries, in most cases annexed to already existing sugar mills. However, implementation of an increasing number of sugarcane independent distilleries and diversification of raw materials for ethanol production will have to change this structure of pricing to a more realistic one decoupled from the traditional sugar industry.

TABLE 43

BREAKDOWN OF ETHANOL SELLING PRICE

- US$ / m^3 -

ITEM	FUEL USE		INDUSTRIAL USE (c)		PETRO-CHEMICAL FEEDSTOCK
	Absolute (a)	Hydrated (b)	Absolute	Hydrated	
Parity Price (d)	295.19	265.18	295.19	265.18	141.31 (e)
Taxes					
. PIS					
- Based on raw material (f)	1.44	1.44	-	-	-
- Over selling price (g)	2.49	2.24	3.02	2.76	2.76
. ICM (h)	33.24	29.87	60.45	55.11	-
. IPI (j)	-	-	28.69	25.84	-
. IAA contribution (f)	-	-	44.33	44.33	44.33
Selling Price (FOB Distillery)	332.36	298.73	431.67	393.20	188.40

Notes:
(a) Minimum ethanol content in absolute alcohol: 99.3% v/v
(b) Minimum ethanol content in hydrated alcohol: 93.9% v/v
(c) For pharmaceutical and cosmetic uses
(d) Parity price for 100% ethanol: US$ 304.20/m^3
(e) 35% of naphtha based ethylene price
(f) Value fixed by IAA
(g) 0.75% over global selling price
(h) Computed as a percentage of global selling price without IPI contribution (fuel: 10%, industrial: 15%)
(j) 8% over global selling price disregarding IAA contribution.

Ref: (37; 59)

On the other hand, competitiveness of ethanol with gasoline or to other petroleum derivates should be kept.

A.3
Taxation

The major Brasilian taxes and levies are briefly reviewed in the following paragraphs.

. IPI (the tax on industrial goods) is a value added tax. The rates at which IPI schedules apply generally increase with the amount of value added. IPI is a consumer's cost. That is, it is levied on the consumer (industrial or individual) whenever a product is purchased. It is calculated as a percentage of the selling price and added to the latter. In the case of industrial consumers, the IPI incurred in the purchase of manufacturing inputs and components is actually recovered by the manufacturer when products are sold. The manufacturer collects the IPI tax paid by the purchaser for the government, and deducts from the amount collected the IPI incurred on inputs and components, then transfers the balance to the government.

. ICM (the tax on the flow of goods) applies to the value added to a product by a manufacturer; each manufacturer keeps an ICM tax account in which credit entries are made when the ICM is applied to the materials and components necessary to manufacture the product; on the other hand, debit entries are made when the ICM is applied to the products sold. At given time intervals the balance of the ICM tax account is paid by the manufacturer to the government. Thus, in commercial terms, ICM is a cost which accrues to the manufacturer.

. PROGRAM FOR SOCIAL INTEGRATION (PIS) is presented with the product sales taxes because it is a tax calculated as a percent of product sales. PIS taxes create a fund for the ultimate use of employees for specific purposes. Prior to such uses the fund may be utilized by the holding bank for various other uses (loans, etc.).

. INCOME TAX is a cost to manufacturers. It applies to the gross operating profit, i.e., revenues from product sales less operating costs. For Income Tax Calculations purposes, some items of cash outflow can be considered as operating costs, such as depreciation and interest on financing.

Income Tax is paid annually in a lump sum or in equal value installments by the manufacturer to the federal government. It is usually due two months after the end of the fiscal year. A current income tax rate of 35% is applied to industrial enterprises.

A.4
Financial Schemes

The following are the conditions for financing projects approved and authorized by PROALCOHOL via CENAL.

A.4.1
Industrial Sector

. Items Entitled to Financing

Financing is available for implementation of the project industrial plant and installations, and includes:

- civil works
- machines and equipment
- installation, erection, freight
- pollution abatement and control equipment, and civil work required for treatment of alcohol production wastes and effluents
- office and laboratory equipment
- feasibility study
- engineering costs
- operating tests
- training expenses
- financing expenses during construction period
- technical assistance
- load handling vehicles, new and domestically made, when part of the overall project
- used mills and their complementary equipment, in the case of independent distilleries and when authorized by the CENAL (Alcohol Executive National Commission)
- costs of filing for approval of the project with CENAL
- storage tanks

The following items, although an integral part of the projects, are not entitled to receive PROALCOHOL financing:

- land acquisition
- acquisition of units already constructed or under construction
- payment of debts contracted prior to submitting the project to CENAL
- used machines or equipment, although overhauled or rebuilt and with operating guarantees or warranties, excepting used mills as indicated hereinabove
- residential units and other installations not essential to the function of the undertaking
- working capital, prior to and after project con lusion
- imported machines or equipment

. FINANCING LIMITS

The financing limit will be established based on the value of the ORTN - Brasilian Treasury Bonds during the month in which the Project is filed with CENAL, and may be:

- up to 80% of the fixed investment, for distilleries based on sugarcane
- up to 90% for distilleries based on other feedstocks such as mandioca.

. FINANCIAL EXPENSES

The financial expenses include monetary correction corresponding to 40% of the variation of the ORTN, plus annual interest rates as shown in Table 44. The Central Bank of Brasil will base its calculations of monetary correction on the June-to-June period immediately preceding the due date of payment.

TABLE 44

PROALCOHOL FINANCING

- ANNUAL INTEREST RATES FOR INDUSTRIAL INVESTMENTS -

(% p.a.)

Type of Project	Location	
	SUDAM/SUDENE (a) (NORTH/NORTHEAST)	Other Regions
Molasses Distilleries	4	6
Independent Distilleries		
- based on sugarcane	3	5
- based on the raw materials	2	2

Note:

(a) SUDAM - Superintendency for the Development of the Amazon Region

SUDENE - Superintendency for the Development of the Norhteastern Region

. REPAYMENT PERIOD

- Distillery projects: 12 years, including up to 3 years of grace

- projects exclusively for alcohol storage capacity at distilleries: up to 5 years, including 1 year of grace.

. GUARANTEES

The usual guarantees suitable in operations with this nature and purpose, at the discretion of the financial agencies.

. RELEASE OF FUNDS

In accordance with the project physical progress schedule.

Disbursements will be based on the value of the ORTN, durinq the month when funds are released.

. REINBURSEMENT

Financial expenses will be reimbursed in semi-annual payments counted from signing of contract. Principal will be amortized in semi-annual payments from end of grace period.

A.4.2
Agricultural Sector

. Items entitled to financing

- Starting or renewing sugarcane fields or other feedstocks intended for alcohol manufacture

- Acquisition of agricultural implements and machinery

- Civil works

- Agricultural upkeep

Financing related to sugarcane growing is conceived as:

- For investment, when intended for:

. Starting or expanding sugarcane plantations, including the preliminary work (clearing the land, removing stumps, etc.), planting (including soil preparation and correction, fertilizing seedlings, etc) and subsequent care required until the first harvest;

. renewing lands in areas previously occupied by cane that has exhausted its productive cycle (first crop, second and third cuttings), encompassing all expenses required until the first harvest.

- For upkeep, when intended to cover expenses of the second and third crops (second or third cuttings), including tilling and partial replanting.

Financing for starting, renewing and upkeep of crops will be granted to molasses distilleries and their suppliers in proportion to the volume of raw material utilized in the production of direct alcohol, subject to prior approval by the Brasilian Sugar and Alcohol Institute (IAA).

. FINANCING LIMITS

When intended for agricultural investment, in accordance with Table 45. When intended for upkeep, up to 100% of the value of the estimated costs, the limits of 80% and 60% of the value of the expected production in the NORTH/NORTHEAST areas and remaining regions of Brasil, respectively, are to be observed with respect to all producers.

. FINANCIAL EXPENSES

The financial expenses for agricultural investment and upkeep operations are shown in Tables 46 and 47, respectively.

TABLE 45

PROALCOHOL FINANCING

- LIMITS FOR AGRICULTURAL INVESTMENT -

Type of Operation	Financing Limits on Estimated Costs (%)
Sugarcane: Initial preparation and renewal of lands and crops	100
Other Investments:	
- mini and small producer (a)	100
- medium size producer (b)	90
- large producer (c)	80
- cooperatives	100

Notes: (a) Annual production up to 400 MVRs (largest reference value established by the Government as a credit unit)
(b) Annual production of 400 to 1000 MVRs
(c) Annual production over 1000 MVRs

TABLE 46

PROALCOHOL FINANCING

- EXPENSES FOR AGRICULTURAL INVESTMENT OPERATIONS -

Region / Type of Producer	ANNUAL EXPENSES (% p.a.)		
	Monetary Correction(a)	Interest	Total
SUDAM/SUDENE (NORTH/NORTHEAST)			
- mini and small producer	-	15	15
- medium-size producer	-	21	21
- large producer	-	26	26
Remaining regions (all producers)	24	5	29

Note: (a) The Central Bank will annually determine the amount of monetary correction, basing its calculation on 50% of the variation in the value of the ORTNs during the annual period, from December to December.

TABLE 47

PROALCOHOL FINANCING

- EXPENSES FOR AGRICULTURAL UPKEEP OPERATIONS -

Region / Type of Producer	ANNUAL EXPENSES (% p.a.)		
	Monetary Correction(a)	Interest	Total
SUDAM/SUDENE (NORTH/NORTHEAST)			
- mini and small producer	-	10	10
- medium-size producer	-	12	12
- large producer	-	15	15
Remaining regions (all producers)	19	5	24

Note: (a) The Central Bank will determine the amount of monetary correction annually, basing its calculations on 40% of the variation in the value of the ORTNs during the annual period, from December to December.

. REPAYMENT PERIOD

For agricultural upkeep: up to one year for sugarcane and two years for mandioca.

For agricultural investment: up to 12 years for fixed capital outlays and 5 years for semifixed capital; however, the following limits will be observed:

- up to three harvests: when utilized for starting or renewing sugarcane crops;
- up to five years: when utilized for fertilizing or intensive soil correction, terracing and renovation of installations or improvements, except for projects located in specific rural development areas, where the repayment period may be up to 12 years;
- up to eight years: when utilized for acquisition of crawler tractors, harvesting machines or other large-size machines.

. GUARANTEES

The usual guarantees required for agricultural operations of this nature, as agreed between the lending agency and borrower.

B. COST MODEL FORMULATION

The objective of this appendix is to develop the mathematical expressions used in the model formulation. A complete list of symbols used in the equation is presented at the end of the text.

The discounted cash flow method was used in the cost model elaboration. All mathematical equations are representative of the present value of the specific item under study. The beginning of the implementation period was taken as the reference data for DCF calculation.

We should emphasize that for a given return rate on investor's capital and financing, the model will calculate the selling price before taxes other than income tax.

B.1 Economic Parameters

Let r be the useful operating life of the project, expressed in years, considered after the implementation period of s years. Thus, the project analysis covers the total span of (s + r) years.

The model provides the possibility of financing the technical assets, C. In this case, we should define some parameters such as:

- x, percentage non-financed, i.e., supplied by own resources;
- n, amortization period, in years;
- k, grace period length, in years;
- j, interest rate, in % p.a., applied to the financed portion of the total investment;
- w, monetary correction, in % p.a.

This last parameter can be equal or lower (subsidized) than the actual currency correction, t (sometimes called inflation).

The discount rates in % p.a., is designated by d. The input prices are corrected annualy multiplying their value by the factor (1 + t) (1 + e) where e is a percentage representing the price increase over and above inflation.

The same concept can be applied to the factor z, the real maintenance cost increase over and above inflation.

B.2
Capital Outlays

. Investment (P_1)

Based on the implementation and disbursement schedule, the present value of the investor's capital outlays during implementation are summarized by:

$$P_1 = \sum_{i=1}^{S} x\, C_i\, (1 + d)^{-\frac{i-1}{12}} \qquad (B.1)$$

Where C_i is the monthly total investment disbursement.

. Financial interest (P) during the grace period.

The present value of the financial interest paid during the grace period is expressed by:

$$P_2 = \sum_{m=1}^{k} j\ (1 - x)\ C \frac{(1+w)^m}{(1+t)^m\ (1+d)^m} =$$

$$= J\ (1-x)C\ \ q\ \frac{1-q^k}{1-q} \qquad (B.2)$$

$$\text{Where } q = \frac{1+w}{(1 + t)\ (1 + d)} \text{ and } C = \sum_{1=1}^{S} C_i \qquad (B.3)$$

If the financial scheme considers a credit opening charge of α (%), it should be added to P_2 in the following form:

$$P_2 = j\ (1 - x)C\ \ q\ \frac{1 - q^k}{1 - q} + \alpha\ (1-x)C \qquad (B.4)$$

. Financial interest and amortization during amortization period (P_3).

At the end of the grace period, the total due is expressed by:

$$B_o = (1 - x)C\ \ (1 + w)^k \qquad (B.4a)$$

This value B should be paid in n equal value instalments, F_o, including interest.

$$F_o\ B_o\ \frac{j\ (1 + j)^n}{(1 + j)^n - 1}$$

The present value to this annual inflated instalment, at a year m of the amortization period, is:

$$P_{3,m} = F_0 \frac{(1 + w)^{m-k}}{(1 + t)^m (1 + d)^m} = F_0 (1 + w)^{-k} q^m$$

Thus, the total value is:

$$P_3 = \sum_{m = k + 1}^{k + n} P_{3,m} = \sum_{m = k + 1}^{k + n} (1-x)C \frac{j(1+j)^n}{(1+j)^n -1} q^m$$

$$P_3 = (1-x)C \frac{j (1+j)^n}{(1+j)^n - 1} q^{K+1} \frac{1 - q^n}{1 - q} \qquad (B.5)$$

. Working capital (P_4)

This item is formed with own resources based on the inventories on inputs and products. In terms of cash flow, working capital is required at the end of implementation. The present value of this disbursement, W, is:

$$W \frac{(1+t)^s \;.\; (1+z)^s}{(1+t)^s \;.\; (1+d)^s} = Wp^s$$

Where: $$P = \frac{1 + z}{1 + d} \qquad (B.6)$$

At the end of the useful operating life, working capital is recovered. The net contribution of working capital can be expressedby:

$$P_4 = Wp^s (1 - p^r) \qquad (B.7)$$

. Residual or salvage value (P_5)

At the end of the useful operating life, s + r years after the beginning of project implementation, there is a cash inflow due to equipment and materials self-value. The present value of the salvage value is:

$$P_5 = \rho C \quad p^{s + r} \qquad (B.8)$$

where ρ is a percentage of the technical assets, C, corresponding to the salvage value of equipment and materials.

B.3
Operating Costs

. Inputs (P_6)

The present value of a specific input cost, at the end of any year during the operating period, is:

$$P_{6,i,m} = E_i \; c_i \; \frac{(1+t)^m \; (1+e_i)^m}{(1+t)^m \; (1+d)^m} = E_i \; c_i \; h_i^{\;m}$$

Where E_i is the annual consumption

c_i is the unit cost including taxes

e_i is the differential increase

$$h_i = \frac{1 + e}{1 + d} \qquad (B.9)$$

The total present value is given by the following expression:

$$P_6 = \sum_{i=1}^{g} \sum_{m=s+1}^{s+r} P_{6,i,m} = \sum_{i=1}^{g} E_i \; c_i \; h_i^{s+r} \; \frac{1-h_i^{\,r}}{1-h_i} \qquad (B.10)$$

. Maintenance (P_7)

The annual maintenance cost, including spare parts and labor, can be expressed as a percentage of the initial investment, μ. The present value of the total maintenance cost during operation is:

$$P_7 = \sum_{m=s+1}^{s+r} P_{7,m} = \sum_{m=s+1}^{s+r} \mu C \frac{(1+t)^m (1+d)^m}{(1+t)^m (1+d)^m}$$

$$P_7 = \mu C \quad p^{s+1} \quad \frac{1 - p^r}{1 - p} \qquad \text{(B.11)}$$

B.4
Revenues (P_8)

The cash inflows are a result of sales of products and byproducts. The annual revenus is given by:

$$P_{8,m} = \sum_{i=1}^{\beta} P_{8,1,m} = \sum_{i=1}^{\beta} D_i \; S_i$$

Where β is the number of products and byproducts

D_i is the annual production of a given i product or byproduct

S_i is selling price of a given i product or byproduct.

The present value of cash inflows is given by the following equation:

$$P_8 = \sum_{m=s+1}^{s+r} \sum_{i=1}^{\beta} D_i \; S_i \frac{(1+t)^m \; (1+e_i)^m}{(1+t)^m \; (1+d)^m} \qquad \text{(B.12)}$$

$$P_8 = \sum_{i=1}^{\beta} D_i \; S_i \; h_i^{s+1} \quad \frac{1 - h_i^r}{1 - h_i}$$

$$B = \sum_{m=k+1}^{k+n} (1+w) \quad B_{m-1} \quad j \frac{1}{(1+t)^m (1+d)^m}$$

$$= \frac{q^m}{(1+w)^k} j \{B_0 (1+j)^{m-k-1} - F_0 \frac{(1+j)^{m-k-1} - 1}{j}$$

$$= (1-x)C \quad q^{K+1} \quad j \frac{1-y^n}{1-y} \{1 - \frac{(1+j)^n}{(1+j)^n - 1}(1 - \frac{1-q^n}{1-q} . \frac{1-y}{1-y^n})\} \qquad (B.13)$$

where y is equal to q (1+j)

Consequently

$$P_{91} = A + B$$

. Inputs (P_{92})

Considered as indispensable costs to the operation of the industrial process, the income tax deduction due to this item is equal to P_6, expression (B.10). Thus:

$$P_{92} = P_6$$

. Maintenance and Insurance (P_{93})

The same same rationale for <u>inputs</u> is applicable to this item.

Thus:

$$P_{93} = P_7$$

. Depreciation (P_{94})

The present value of the linear depreciation of the investment over $\underline{\ell}$ years is:

$$P_{94} \quad \sum_{m=s+1}^{s+\ell} \frac{C}{\ell} \quad \frac{1}{(1+d)^m} = \frac{C}{\ell} \quad \frac{1}{(1+d)^s} \frac{(1+d)-1}{d(1+d)^\ell} \qquad (B.14)$$

B.5
Income Tax Deductions (P_9)

This paragraph is dedicated to the evaluation of the cost items that can be deducted from the gross profit for income tax purposes. These items include: interest, inputs, maintenance, insurance and depreciation.

. Interest (P_{91})

Interest is paid during grace and amortization periods for the financed portion of the investment.

It is assumed that each payment of interest made during grace period was referred to the end of this period. Then the sum of these partial values is treated as a depreciation over a period of f years (generally 5 years). The mathematical expression is:

$$A = \sum_{m=k+1}^{k+f} \frac{1}{f} \quad j(1-x)C \quad v \frac{1 - v^k}{1 - v} \qquad \frac{1}{(1+d)^m} =$$

$$= \frac{1}{f} \; j\,(1-x)C \quad v \frac{1 - v^k}{1 - v} \; \frac{(1+d)^f - 1}{d\,(1+d)^f} \quad \frac{1}{(1+d)^k} \qquad (B.12)$$

where $V = \dfrac{1 + w}{1 + t}$

The second part corresponds to the interest paid during amortization. Updating of financed portion of the investment is given by expression (B.4a).

After discounting the amortization and interest, the value of the financed money will be at a given year m-1.

$$B_{m-1} = (1+w)^{m-k-1} \{B_0 \; (1+j)^{m-k-1} - F_0 \sum_{i=0}^{m-k-2} (1+j)^i\}$$

The present value of the interest calculated over this net value is:

A typical value for $\underline{\ell}$ is 10 years although this parameter is a function of the type of the investment.

Therefore, the sum of each income tax deduction can be written as:

$$P_9 = \sum_{i=1}^{4} P_{9_i} \qquad (B.15)$$

B.6
Discounted Cash Flow Equation

It should be borne in mind that the objective is to calculate the selling price of the principal product of an agroindustrial system. Through the equation of the DCF at the beginning of the implementation of the project, the only unknown, the selling price of the main product, will be calculated. This equation in present value terms is:

$$P_8 - (P_6 + P_7) - (P_8 - P_9)\,\Theta + P_{9_4} = P_1 + P_2 + P_3 + P_4 - P_5$$

where Θ is the percentage of income tax, in %

Thus,

$$P_8 = \frac{P_1 + P_2 + P_3 + P_4 + P_6 + P_7 - P_5 - P_{9_4} - P_9\,\Theta}{1 - \Theta} \qquad (B.16)$$

Discounting the revenues from byproduct sales from the value of P_8 we get the present value of revenue from the main product sales. The distribution of this quantity in equal parts over the operating period of the project will yield the calculated selling price, as stated in the equation below:

$$S_1 = \{P_8 \quad \sum_{i=2}^{\beta} D_i \; S_i \; h_i^{s+1} \quad \frac{1 - h_i^{r}}{1 - h_i}\} \; \frac{d(1+d)^{r+s}}{(1+d)^{r} - 1} \quad \frac{1}{D_1} \qquad (B.17)$$

where D_1 is the quantity of main product generated annually.

B.7
Nomenclature

A - Income Tax deduction due to interest paid during grace period

B - Income Tax deduction due to interest over financed portion of total investment, paid during amortization

C - Total initial investment

C_i - Total initial investment

C_i - Unit Cost including taxes

D_i - Annual production of products and byproducts (Unit/yr)

d - Rate of return (% p.a.)

E_i - Annual input consumption (Unit/yr)

e_i - Differential input cost increase, overt the inflation (%)

f - Depreciation time for interest during grace period (year)

g - Number of process inputs

h_i - $(1 + e_i) / (1 + d)$

j - Interest rate (% p.a.)

k - Grace period length (year)

ℓ - Depreciation time for the investment (year)

n - Amortization period length (year)

P_i - Present value of various components of DCF

P - $(1 + z) / (1 + d)$

q - $(1 + w) / \{1 + t) . (1 + d)\}$

r - Useful operating life span (year)

S_i - Selling price of a given i product or byproduct

s - Implementation period length (year)

t - Inflation or monetary correction (% p.a.)

v - $(1 + w) / (1 + t)$

W - Working capital

w - Subsidized monetary correction

x - Portion of investor's resources on Total Investment (%)

y - q. (1 + j)

z - Differential products and services cost increase, over the inflation (%)

μ - Maintenance (% of total investment)

ρ - Salvage value (% of total investment)

Θ - Income Tax Rate (%)